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THE MONOCLINIC PYROXENES
OF NEW YORK STATE.

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III.—*The Monoclinic Pyroxenes of New York State.*

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INTRODUCTION.

The following paper is intended to give the results of a crystallographic, chemical and optical investigation of the monoclinic* pyroxenes occurring within New York State, and to this is added such information as has already been published by others.

In the course of this work the pyroxenes in the collections of the following institutions have been examined: School of Mines, Columbia University; American Museum of Natural History, New York City; The New York State Museum, Albany, N. Y.; Rutgers College, New Brunswick, N. J.; National Museum, Washington, D. C.; Hamilton College, Clinton, N. Y.; Cornell University, Ithaca, N. Y.; Williams College, Williamstown, Mass.; as well as the private collections of Prof. Thos. Egleston, Prof. A. H. Chester and Mr. F. L. Nason.

* This does not include wollastonite.

A constant difficulty all through the work has been the lack of fresh material for chemical and optical work, so that crystallographic portion of the paper predominates.

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GENERAL CHARACTERS OF PYROXENE.

The Pyroxene group includes minerals which are for the most part normal metasilicates of the general formula RSiO_3 . They are simple silicates involving a single base (as Wollastonite) as well as isomorphous mixtures of several. They also sometimes depart from the normal metasilicate type in that they often contain an excess of iron oxide or alumina. All the monoclinic pyroxenes are isomorphous mixtures of more than one base. Hintze makes the following varieties :*

Diopside.	$\text{MgCa Si}_2\text{O}_6$
Sahlite.	$(\text{MgFe}) \text{CaSi}_2\text{O}_6$
Hedenbergite.	$\text{CaFeSi}_2\text{O}_6$
Schefferite.	$(\text{MgFe}) (\text{CaMn}) \text{Si}_2\text{O}_6$
Jeffersonite.	$(\text{MgFeZn}) (\text{CaMn}) \text{Si}_2\text{O}_6$
Augite.	$\left[\begin{array}{l} (\text{MgFe}) \text{CaSi}_2\text{O}_6 + \\ (\text{MgFe}) (\text{AlFe})_2 \text{Si O}_6 \end{array} \right]$

Pyroxene crystallizes in the monoclinic system, and the crystallographic relations of the different members vary but little. The members are theoretically of different composition, although they nevertheless grade into each other.

The axial ratios upon which measurements are usually reckoned are those calculated by G. V. Rath on augite from Vesuvius (Pogg. Ann. 1873, Erg. Bd. VI, p. 340.)

$$a : b : c = 1.09213 : 1 : 0.58931.$$

$$\beta = 74^\circ 10' 9''$$

The habit of pyroxene crystals is usually columnar parallel to c (001), those of augite tending towards a short thick form, while those of diopside are often slender. In cross-section they are frequently rectangular or square from the great development of a (100) and b (010) but they are sometimes tabular, and if so the flattening is parallel to a (100).† (The New York pyroxenes are an exception to this rule). Hemihedrism is known to occur, but it is very rare. Twinning is commonest parallel to a (100) and sometimes parallel to c (100). Hintze also mentions twins parallel to y (101) and W ($\bar{1}22$). The twinning line often runs through the middle of the crystal and in this case gives no reen-

* Handbunch der Mineralogie, p. 1016.

† Hintze, Handbuch der Mineralogie, p. 1019.

trant angle. Lustre vitreous to dull. Crystals often transparent especially in the diopsides. Color mostly green, but varies from colorless through various shades of green to black, also brown and yellow. Streak white, green or gray. Fracture conchoidal.

Cleavage parallel to m (110). Parting parallel to c (001) and a (100). Hardness 5-6., Sp. Gr. 3.2-3.6.

Etch figures on diopside usually show triangles the acute angles of which point in the direction of the positive hemi-pyramid, or a deltoid with rounded sides, whose acute angle points towards the negative and obtuse angle toward the positive pyramid. A parallelogram is formed on the clino-pinacoid.

The plane of the optic axes coincides with the plane of symmetry, and the acute bisectrix lies in front of the vertical axis. Pyroxene is optically positive. $c:c$ varies from 36° - 54° .

Tschermak* claimed that the variation of the extinction angle is due to the chemical composition and that it is especially influenced by the percentage of iron in the non aluminous ones. He noticed that a change of color was accompanied by a change in the angle which the optic axis made with the normal to a . F. J. Wiik† claimed that $c:c$ increased with the percentage of FeO in the Finnish pyroxenes. He, however, found that there were pyroxenes which would not fit this rule, and came to the conclusion that the pyroxenes of the younger volcanic rocks followed a different law.

Herwig‡ made a long series of similar determinations, but they showed no deducible law.

Doelter§ found in a series of augites that the FeO percentage (in those containing no Fe_2O_3) had an effect on the optical properties. No regular law could be formulated if Fe_2O_3 were present or if the sum of FeO and Fe_2O_3 were used. A better curve was obtained when the sum of FeO, Fe_2O_3 and Al_2O_3 was taken. A regular curve was only obtained when the sum of the amounts of the component silicates are taken.

Flink found that manganese had the same effect as iron on the extinction angle.

According to Des Cloiseaux|| an increase of temperature pro-

* Min. Mitth., 1871, p. 21.

† Zeitschr. für Kryst. u. Min., VIII, p. 78 and 208.

‡ Ibid, XI, p. 67.

§ Neues Jahrb., 1885, I, p. 56.

|| Nouv. rech., 1867, p. 649.

duces a change in position of the optic axes and bisectrices. In a section normal to the acute bisectrix an increase of temperature from 17° to 196° C caused the optic axes of light colored pyroxenes to wander $1^{\circ} 34'$ from their original position; with more intensely colored ones the change was $0^{\circ} 36'$.

Pleochroism is generally weak, and is found chiefly in the darker varieties, the light colored ones being non-pleochroic.

The specific heat of pyroxene has been determined on the black diopside from Nordmarken, Sweden, and found to be 0.1830.

The different varieties of pyroxene may be defined as follows:

DIOPSIDE. $\text{CaMgSi}_2\text{O}_6$ or SiO_2 , 55.60%; CaO , 25.90; MgO , 18.5. Color white, yellowish, grayish white to pale green, or even black. Crystals often transparent and colorless. The crystals are usually slender and prismatic, and iron is frequently present in small amount.

Malacolite as originally used referred to a bluish-gray or grayish-green variety. Rosenbusch classes under this term those rock-making monoclinic pyroxenes poor in alumina or free from it, and not laminated parallel to the orthopinacoid. *Alalite*, *Traversselite* and *Canaanite* are merely locality names.

HEDENBERGITE. $\text{CaFeSi}_2\text{O}_6$, or SiO_2 , 48.40; FeO , 29.40; CaO , 22.20. Occurs in crystals or in lamellar masses, of a black color.

SAHLITE. This is placed by Dana as a sub-variety, but Hintze makes it a full species, having the composition $(\text{MgFe})\text{CaSi}_2\text{O}_6$. The color is usually grayish green, and the name is derived from the type occurrence at Sala, Sweden.

Diallage. According to Dana* the composition is near diopside, but it often contains a considerable percentage of alumina. Its chief characteristic is a lamellar structure due to a parting parallel to the orthopinacoid, sometimes another parallel to the clinopinacoid and less often one parallel to the base.

Coccolite was first applied to a dark green variety rich in iron from Arendal, but is now used to designate any granular variety of pyroxene.

AUGITE includes the aluminous monoclinic pyroxenes. It varies more in composition probably than any of the other varieties. Dana gives the composition as $\text{CaMgSi}_2\text{O}_6$ with (MgFe) $(\text{AlFe})_2\text{SiO}_6$, and Hintze gives it as $(\text{MgFe})\text{CaSi}_2\text{O}_6 + (\text{MgFe})$

*System of Mineralogy, 1893.

(AlFe)₂SiO₆. The color is usually green to black, and the habit of the crystals is short and stout.

Leucaugite is a name given to white or grayish varieties, with alumina, lime, magnesia and little or no iron.

The varieties described above are purely theoretical and no fixed line of division exists, for all stages of transition in composition between the different ones may occur.

In treating of the pyroxenes of New York State the writer has for convenience set an arbitrary line of division, classing as diopside those with less than 3% of alumina and as augite those containing more than that amount.

DISTRIBUTION OF THE PYROXENES IN NEW YORK STATE.

There is in the eastern portion of New York State an extensive area of igneous and metamorphosed rocks which are bordered by the Cambrian and Silurian strata of sedimentary origin, and into which they have often penetrated. Where the limestone is in contact with the igneous rock it not only becomes more coarsely crystalline, but there are also developed in these contact zones a number of minerals chief among which are pyroxene, amphibole, wollastonite, scapolite, garnet, tourmaline, feldspar, titanite, zircon.

This large igneous area forms the Adirondack *massif* west of Lake Champlain, and which extending through Clinton, St. Lawrence, Essex and Jefferson Counties, includes a series of (Ref. 29 and 30) quartz-orthoclase gneisses with biotite or augite, crystalline limestones often shading to opicalcites on the east and closely associated with black hornblendic and pyroxenic gneisses on the west, and thirdly a great series of intruded plutonic rocks on the Gabbro family.

In this region the pyroxene occurs in the form of small grains and crystals as a primary constituent of the gabbros and gneisses, as well as in the limestones and opicalcites at or near their contact with the intrusive masses. In the limestone, the pyroxene begins to appear in scattered grains as the contact is approached, and these increase in number and degree of development until at the contact the limestone is often filled with an interlacing mass of crystals while between it and the intrusive there is often a space lined with well-formed and sometimes quite large pyroxene crystals. Other minerals may occur as well, and the space be-

tween is frequently filled with calcite. The igneous rock also becomes more pyroxenic as the zone of contact is approached. The most important of these contact localities are at Russell, East Russel, Gouverneur, Pierrepont, Diana, Natural Bridge, Rossie, Oxbow, Dekalb and Edwards.

The small beds of opihalcite of the eastern Adirondack region contain an abundance of pyroxene in grains and crystals, which are either disseminated through the rock or else collected with other minerals in the form of large bunches of silicates in the limestone. An excellent illustration of these bunches of silicates appears in a recent paper by Prof. J. F. Kemp. (See Ref. 30.)

In this same region the pyroxene not unfrequently occurs in intimate association with the ore-bodies, either as well developed crystals, or forming granular streaks between the ore bed and the wall rock.

The pre-cambrian rocks of the Highland region in southeastern New York are composed of a series of gneissic and granitic rocks, interbedded limestones and beds of iron ore, the whole intersected by many dikes. The conditions of occurrence of pyroxene in this region are therefore somewhat similar to those found in the Adirondacks. While it occurs in grains and anhedral* in many of the gneissic rocks and dikes its best development is around the beds of magnetite. The most important localities are at the O'Neil Mine, the Bradley Mine and the Sterling Mines. Owing to the cessation of mining these localities are practically exhausted.

To the southwest of the Highland region the area around Mts. Adam and Eve is of great importance, for the intrusion of the granite into the limestone has given rise to a rich development of contact minerals, pyroxene being among the best developed. Most of the specimens have been found near Edenville.

The gabbros and diorites of the Cortlandt Series, near Peekskill, Westchester Co., contain an abundance of pyroxene, and the same mineral has been formed as a result of contact metamorphism in the surrounding limestones (Ref. 61 and 63). The same is true of the Rosetown extension of this area across the Hudson River (Ref. 22).

* L. V. Pirsson. Philadelphia Meeting Geol. Soc. Amer., Dec. 1895.

Other isolated pyroxene occurrences are at the Tilly Foster Mines, Putnam Co., and at New Rochelle, Westchester Co., the former associated with magnetite in gneiss and the latter with serpentine.

Pyroxene is very abundant at certain localities in the dolomitic limestones of Dutchess, Putnam, Westchester and New York Counties. The crystals all bear the closest resemblance to one another, and are found singly, in streaks, or in clusters lining cavities. A massive form of the same species occurs at times. The important localities are Kingsbridge, New York Co., Sing Sing, Westchester Co., Pawling and Paterson, Dutchess Co. The dolomites in which these pyroxenes occur have been highly metamorphosed by dynamic action.

It will be seen from the foregoing that the pyroxenes occur in New York State under the following conditions: 1. As primary constituents of igneous rocks. 2. In the contact zones between the limestones and intrusive rocks. 3. In crystalline limestones in areas of regional metamorphism. 4. Associated with the iron ore bodies.

In general, it may be said that the lighter colored varieties occur in the limestone, while the darker ones are found along the contact zones and in the igneous rocks. The minerals usually found associated with the pyroxene are scapolite, feldspar, wolastonite, amphibole, titanite, mica, tourmaline, garnet, chondrodite, zircon and quartz. The pyroxene occurs both massive or in crystals that are scattered through the rocks or that form clusters lining veins or cavities. These latter are generally filled in with calcite or quartz.

GENERAL CHARACTERS OF THE NEW YORK PYROXENES.

CRYSTALLOGRAPHY.

The forms occurring are comparatively few in number, but the combinations and their relative development of faces are, in most instances, quite characteristic of the locality. These peculiarities are mentioned under the detailed descriptions of the different localities. The great majority of the specimens found only show faces in the prismatic zone, owing to adverse conditions of growth. Doubly terminated individuals are not uncommon but they have not been observed from every locality.

The following faces have thus far been noted on the New York Pyroxenes:

$m(110) \propto P$	$u(111) - P$
$f(310) \propto P3$	$s(111) P$
$a(100) \propto P \propto$	$v(221) - 2P$
$b(010) \propto P \propto$	$o(221) 2P$
$c(001) OP$	$\lambda(331) 3P$
$e(011) P \propto$	$\Delta(311) 3P3$
$z(021) 2P \propto$	$\mu(121) - 2P2$
$p(101) P \propto$	$\alpha(312) - \frac{2}{3}P3$

Prisms. The unit prism $m(110)$ is a very common face and is almost invariably present. It may or may not exceed the ortho and clino pinacoids in size. The ortho-prism $f(310)$ has only been observed on one crystal from this state and that from the Tilly Foster Iron Mine in Putnam Co. It has not been previously recorded from New York State, but is common on many European pyroxenes.

Pinacoids. The ortho pinacoid $a(100)$ and the clino pinacoid $b(010)$ are as common as the unit prisms, but show great variation in their development. When of equal size and greater development than the prism the section of the crystal is square. A greater development of one of the pinacoids gives the crystal a tabular habit. Thus the white pyroxenes from Sing Sing, Westchester Co., are nearly always tabular parallel to a while those from St. Lawrence Co. are not uncommonly tabular parallel to b . The basal pinacoid $c(001)$ is often seen on terminated crystals. A basal parting may give the same appearance to the crystal. The basal pinacoid face is generally rectangular in outline, but this varies somewhat depending on the number of faces which intersect it.

Domes. Two clinodomes and one orthodome occur. The latter is the commonest of the three. It is rarely present without the basal pinacoid and is generally smaller than it. A characteristic exception to this rule is found in the augites from Mt. Adam, Orange Co., and those from the Tilly Foster Iron Mine in Putnam Co. The two clinodomes $e(011)$ and $z(021)$ are generally represented by small triangular faces. The dome z is rare, but the dome e is quite a characteristic form on many augites from the Highland Region of Orange Co.

Pyramids. Terminated crystals as a rule show the positive and negative unit pyramids and the positive pyramid o (221). The latter is rarely present without the other two. The pyramid v (221) is rare and usually small when present. A notable exception to this is the white augite found in the dolomitic limestones of Dutchess, Westchester and New York Counties. The Δ (311) has only been observed on crystals from two localities, viz., Russell and De Kalb and the pyramid λ (331) is even rarer and found on crystals from Diana, Lewis Co., μ (121) and α (312) have only been noted on augite of Orange Co.

A curious inequality of development is shown by the diopsides of DeKalb, on which one face of u (111) is often large, while the other is so small as to appear absent.

The pyramid faces are often dull or even slightly rough, and seamed with a series of longitudinal pits.

The accompanying table gives the distribution of the different faces found on the New York pyroxenes.

TABLE GIVING OCCURRENCE OF CRYSTAL FORMS AT THE DIFFERENT LOCALITIES.

LOCALITY.	a	c	b	m	f	e	z	u	s	v	o	λ	Δ	p	μ	α
Adams' Lake.	*	*	*	*		*		*	*		*				*	
Cheever.	*	*	*	*				*	*		*					
Chilson Hill.	*	*	*	*				*	*		*					
DeKalb.	*	*	*	*		*		*	*	*	*		*	*		
Diana.	*	*	*	*			*	*	*	*	*					
Gouverneur.	*	*	*	*				*	*	*	*					
Greenwood Lake.	*	*	*	*						*						
Hammondville.	*	*	*	*				*								
Highlands of Hudson.	*	*	*	*		*										
Kingsbridge.	*	*	*	*						*	*					
Macomb.	*	*	*	*				*								
Monroe Township.	*	*	*	*		*	*	*	*	*	*				*	
Natural Bridge.	*	*	*	*			*	*	*	*	*					
Oxbow.	*	*	*	*				*	*	*	*					
Pawling.	*	*	*	*						*	*					
Pierpont.	*	*	*	*												
Pitcairn.	*	*	*	*				*	*		*				*	
Port Henry.	*	*	*	*		*		*	*		*				*	
Rossie.	*	*	*	*				*	*		*					
Russell.	*	*	*	*				*								
Sing Sing.	*	*	*	*						*	*				*	
Tilly Foster.	*	*	*	*	*	*		*	*	*	*				*	
Warwick.	*	*	*	*				*	*	*	*				*	*

Cleavage. A well-developed prismatic cleavage is often present. Sometimes it is only apparent in thin sections, but at others is so pronounced as to cause the crystals to cleave easily. An orthopinacoidal cleavage is said by A. R. Leeds to occur in the pyroxenes of the Adirondack region (Ref. 34), but it is probably a parting.

Parting. There exist two pronounced partings due to twinning, one parallel to the base, the other to the orthopinacoid. The former is the more abundant and is seen on specimens from nearly every locality.

Both show themselves on the surface by the existence of numerous striae.

Twinning occurs after two laws, viz., parallel to the base and orthopinacoid, the former being the most common. Usually the only outward evidence of the fact is the striated surface referred to in the preceding paragraph.

The twinning may be repeated, the alternate twin lamellæ being generally extremely thin. At times there is only one twinning plane which passes through the centre of the crystal, parallel to the orthopinacoid, thus producing twice the number of faces of the same symbol at one end of the individual.

A curious case of twinning is noted by Prof. G. H. Williams on a crystal from Orange Co., in which the lower half of the crystal alone is twinned. (Ref. 60.)

Perfectly fresh crystals do not generally show twinning.

Hemihedrism.—According to Prof. G. H. Williams this has been shown to occur on crystals from two localities in New York State (Ref. 62). One example is a crystal from Orange Co., which shows planes of different forms grouped about opposite extremities of the vertical axis. From its occurrence on several crystals this inclined hemihedrism seems to be not altogether rare. The Orange Co. crystal shows $c(001)$, $s(111)$, $o(221)$, $e(011)$ and $u(111)$ at the upper end and $c(001)$ and $u(111)$ at the lower. Another crystal from this same locality shows $c(001)$, $s(\bar{1}11)$, $o(\bar{2}21)$ and $u(111)$ above, and below the two halves of the crystal in twinning position and with only $o(221)$ and $p(101)$. The crystal was carefully tested by Prof. Williams but showed no pyro-electricity. A second instance of hemihedrism is noted in a crystal from Grassy Lake, St. Lawrence Co., with $u(111)$, $s(111)$, $o(221)$ at one end and $p(\bar{1}01)$, $c(001)$, $u(111)$, $s(\bar{1}11)$ and $o(221)$ at the other.

These crystals were first called by Prof. Williams hemimorphic, but subsequently the term hemihedral was used by him.

OPTICAL PROPERTIES.

With the exception of an approximate determination of the extinction angles of the pyroxenes occurring in the igneous and metamorphic rocks of New York State, the only optical determinations which have been made are those by K. Zimanyi on DeKalb diopside (Ref. 64), and by C. Doelter on augite from Greenwood Furnace. (Ref. 14.)

This may be due to the fact that New York does not abound in fresh glassy crystals whose condition would be such as to encourage optical investigation.

Relation between the optical and chemical properties.

The researches of Wiik, Doelter and Herwig have already been mentioned in the introductory portion of this paper, and in order to determine how far the writer's results agree with theirs the following table was made, giving the extinction angle, and the percentages of FeO, Fe₂O₃ and Al₂O₃.

LOCALITY.	$c \wedge t$	FeO.	Fe ₂ O ₃ .	Al ₂ O ₃ .	Sum of Three.
Russel.....	37°	1.29		2.42	3.71
DeKalb.....	40°	1.12		.40	1.52
Sing Sing.....	40°	.80		4.11	4.91
Port Henry.....	41°	1.80		1.32	3.12
Pitcairn.....	41° 30'	1.301		3.09	4.391
Diana.....	41° 30'	8.63	.50	4.94	14.07
Greenw. Furn...	42° 20'	2.55	5.05	5.09	12.64
Warwick.....	45° 15'	6.86	.57	5.82	13.25
Cheever.....	52°	15.98	3.53	7.49	27.00

An examination of the above table shows that the extinction angle does not increase with the percentage of FeO, thus showing a disagreement with Wiik's results, although it should be added that Wiik found several exceptions to his rule. Comparing the extinction angles with the corresponding sum of the ferrous and ferric iron gives no better results. If, however, the combined percentages of FeO, Fe₂O₃ and Al₂O₃ be taken, a more regular series is obtained, the greatest variation being the pyroxene from Russel. If, furthermore, those containing under 3% of Al₂O₃ be excluded from the list as belonging more properly to the diop

sides a still better series is obtained, but not a perfectly regular one.

Indices of Refraction.

These were determined by the Kohlrausch method,* on specimens from all localities furnishing sufficiently fresh material. The measurements were made on polished surfaces, but the reflections afforded were often rather weak. For the sake of comparison the indices of refraction for yellow light are given below :

	α	β	γ
Russel.....	1.6626	1.6718	1.6940
Port Henry	1.6683	1.6730	1.6902
DeKalb †.....	1.6674	1.6745	1.6961
DeKalb	1.6749	1.6852	1.7013
Sing Sing.....	1.6778	1.6848	1.7025
Pitcairn	1.6806	1.6843	1.7036
Diana.....	1.6883	1.6932	1.7108

It will be seen that the index of the Russel diopside is the lowest of the series, and lower in fact than any recorded in Hintze's *Handbuch der Mineralogie*, where a number of determinations made on pyroxenes from various localities are given.

Axial Angles.—The axial angle is known to vary with the chemical composition in the same manner as the extinction angle, the increase of the angle with the corresponding increase of iron and alumina does not seem to be as regular, however, as the enlargement of the extinction angle, and also, the axial angle does not increase with the extinction angle.

The following table may serve to illustrate this fact :

	$c \wedge z$.	2 Vna.	Sum of FeO, Fe ₂ O ₃ , Al ₂ O ₃ .
Russel.....	37°	58° 56'	3.71%
DeKalb	40°	59° 30'	1.52%
Sing Sing.....	40° 10	59°	4.91%
Port Henry.....	41°	56° 30'	3.12%
Pitcairn	41° 30'	59° 40'	4.391%
Diana	41° 30'	60° 40'	14.07%

The same disagreement between the extinction angle and the axial angle, is shown by the following measurements ‡ of pyroxenes from other localities.

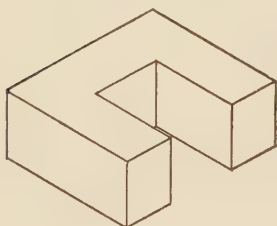
* Methylene iodide with index of 1.732 was used.

† Determined by K. Zimanyi, see Ref. 60.

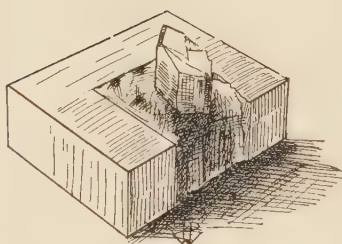
‡ Hintze, *Handbuch der Mineralogie*, p. 1026-1029.

LOCALITY	$c \wedge z$	2 Vna
Diopside, Nordmarken.....	38° 3½'	58° 52'
White pyroxene, Kussinsk, Ural.....	38° 34'	58° 45'
Diopside, Schwarzenstein, Tyrol	39° 4'	58° 56'
Green coccolite, Arendal	40° 22'	58° 38'
Schefferite, Langban.	44° 25½'	65° 3'
Diopside, Nordmarken.....	44° 42'	60° 28'
“ “	45° 21'	66° 44'
Hedenbergite, Tunaberg.....	47° 10'	59° 52'
Augite, Frascati	54°	68°

METHOD OF CUTTING SECTIONS AT RIGHT ANGLES TO THE ACUTE BISECTRIX.



In cutting sections of the crystals for the purpose of measuring the axial angle some difficulty was at first experienced in getting the section cut at just the desired angle, as no saw for sectioning brittle minerals in any desired direction was at hand. The following method was devised and on account of its simplicity and the uniformly good results obtained seems worthy of mention.

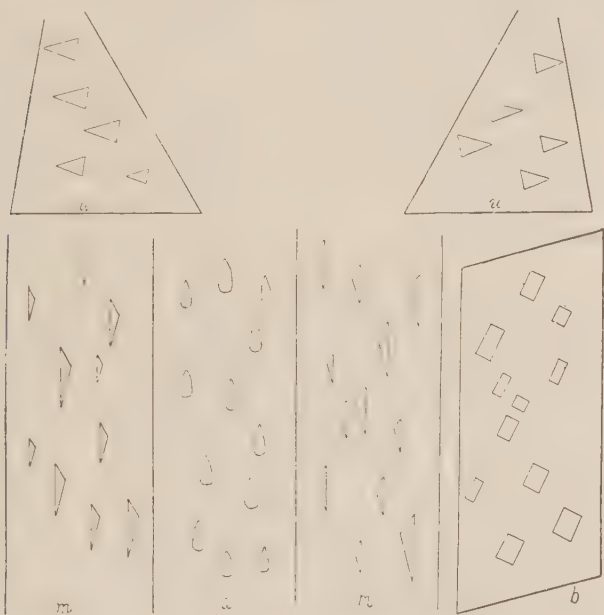


A frame of hard polished steel was made of the shape, shown in the upper part of Fig 1. On the clinopinacoidal face, or a ground plane corresponding to it, there is scratched a line representing the trace of a plane normal to the acute bisectrix. The crystal is then fastened in the frame with a piece of wax so that the line coincides with the upper surface of the frame, and plaster of paris poured in around it and allowed to harden. The crystal is thus firmly embedded in the frame as shown in the lower cut of the figure, and is ground down until its surface is even with that of the steel frame. The crystal is then removed, the ground surface polished and cemented to a glass slip and the other end of the crystal ground down in the usual way.

The section giving a perfectly symmetrical and satisfactory interference figure was obtained at every trial. The smallest crystal sectioned was three-eighths of an inch long and the same in width.

ETCHFIGURES.

Crystals of diopside from DeKalb and augite from Pitcairn, showing smooth and bright faces, were treated with warm hydrofluoric acid for several minutes, and in both cases with the following results:



On the prism face there was produced an acute angled triangle, whose longer side was parallel, or very nearly so, to the edge $110 \wedge 010$. The acute angle always pointed towards the positive hemipyramid, while the obtuse angle pointed towards the orthopinacoid.

On the orthopinacoid the etchfigures were irregularly deltoid in outline, with the lower end rounded, and the upper end always drawn out into a point which was towards the negative hemipyramid.

Somewhat irregular figures were produced on the clinopinacoid,

but those which far exceeded all the others in numbers were rectangles, whose longer side made an angle of 25° , with the edge $010 \wedge 110$. The upper sides of these rectangles are parallel to the intersection of 010 and 011 .

A triangular figure was produced on the negative unit pyramid face, whose acute angle pointed toward the edge $111 \wedge \bar{1}11$. The base of the triangle made an angle of 15° , with the edge $111 \wedge 110$.

Very unsatisfactory figures were obtained on the basal pinacoid. The majority were squares whose sides were respectively parallel and perpendicular to the plane of the orthopinacoid. There were also a few pits whose outline was closely that of an equilateral triangle.

The results noted above agree very closely with those obtained by Wulffing* on diopsides from Ala., and by Greim†. Greim states that the triangular pits were sometimes truncated by a fourth plane, but this was not noticed by the writer on any of the crystals etched by him.

CHEMICAL COMPOSITION.

As previously stated pyroxene is divided into several varieties of definite theoretical composition. It rarely happens that the analysis when calculated out gives a formula which corresponds exactly to any of these, but instead, the pyroxene is found to consist approximately of an isomorphous mixture of several metasilicates.

Rammelsberg‡ put forth the theory that in aluminous pyroxenes, the ferric iron and alumina were present as sesquioxide and mixed with the normal metasilicates, thus giving the general formula $n \ddot{R} \text{SiO}_3 + \ddot{R}_2 \text{O}_3$, while the pyroxenes with no alumina were simple mixtures of isomorphous silicates.

Tschermak§ subsequently showed that in many cases in the alumina free augites $\text{Ca}=\text{Mg}+\text{Fe}$, while in the aluminous ones $\text{Ca}<\text{Mg}+\text{Fe}$.

The writer has attempted in each case to calculate the mixture of metasilicates present. (See detailed accounts of localities).

*Beiträge zur Kenntniss der Pyroxenfamilie in Chemischer und Optischer Beziehung.--Heidelberg, 1891.

†Neues Jahrbuch für Mineralogie, 1889, p. 252.

‡Zeitschr. d. d. geol. Ges., 1876, p. 496.

§Min. Mittheil., 1871, p. 17-46.

This was sometimes possible, but at other times the result was not exact, due perhaps to impurities or a slight error in the analysis. In all the analyses made by the writer the material was finely powdered and then treated with a magnet and afterwards with a specific gravity solution.

An examination of the formulæ calculated shows the presence not uncommonly, of the wollastonite or orthorhombic pyroxene molecule. There also remains at times an amount of SiO_2 .

The analyses further indicate that Tschermak's theory of the relation between Al_2O_3 and the oxides of Ca, Mg and Fe holds good in the case of only about one-half of the New York pyroxenes analyzed, as will be seen from the following table:

ALUMINOUS PYROXENES.		
Ca.	Mg+Fe.	LOCALITY.
.4041	> .3961.....	Cascadeville.
.4278	> .3028.....	Diana.
.386	> .1847.....	Keene.
.31	< .379	"
.3353	< .4282.....	Mt. Marcy.
.3825	< .492	Pitcairn.
.309	< .373	Pt. Henry.
.4166	> .2640.....	Rogers Rock.
.4107	> .3545.....	"
.368	< .465	Greenwood Furnace.
.277	> .189	Rosetown.
.480	> .375	Warwick.
.458	> .3655.....	Edenville.
.4432	> .4156.....	Sing Sing.
.375	> .359	West Point.
.345	< .453	Willsborough.
.394	< .419	Edenville.

ALTERATION PRODUCTS.

Uralitization is the almost universal method of alteration. It begins with the appearance of a fibrous structure on the surface of the crystal, especially the prism faces, and gradually extends through the entire individual. This change is well shown in the pyroxenes of Russel and Pierrepont. The white varieties alter to tremolite, as shown by the white pyroxenes of Kingsbridge and Sing Sing.

These paramorphs of hornblende after pyroxenes are well shown in the gabbros of the Cortlandt Series near Peekskill, where there

is a direct change to compact black hornblende. Prof. Williams has stated that the tendency of the pyroxene molecule to assume the form of hornblende is sufficient to affect a complete change in the crystalline structure, but if "some external agency could be introduced, which would render the molecules more or less mobile without increasing the temperature to a point where the augitic mode of arrangement is more stable than the hornblende, it will be readily seen that they must assume the form best in accordance with the lower temperature." He also thinks that just such an external agency as this would be furnished by the pressure to which the rocks are subjected in mountain making (Ref. 59).

A second and not uncommon alteration product is serpentine. This change is well shown in the opicalcites of Warren and Essex Counties. The serpentine grains show a core of unaltered pyroxene, and all stages in the transition may be seen. The composition of the serpentine and pyroxene are given below (Ref. 38).

	Pyroxene.	Serpentine.
SiO ₂	55.26	42.17
Al ₂ O ₃	.22	.30
Fe ₂ O ₃	.22	1.57
FeO	.57	.64
MgO.....	19.53	41.33
CaO	24.48	
MnO.....	tr	tr
H ₂ O		13.72
	100.28	99.73

As will be seen from the above analyses, the change consists in the assumption of water and the loss of lime, which crystallizes out as calcite.

Chlorite has been observed as a result of the alteration of augite in a few instances (Ref. 15, 48, 49).

Pink garnet frequently appears to result from the alteration of the augites in the Adirondack gabbros (Ref. 29). The two minerals occur in very close association, and the same cracks often traverse both. The following is an analysis of the pyroxene and the garnet:

	Pyroxene.	Garnet.
SiO ₂	56.00	43.38
FeO	2.40	
CaO.....	21.63	22.61

	Pyroxene.	Garnet.
MgO.....	5.23	10.50
Fe ₂ O ₃	4.70	17.08
Al ₂ O ₃	8.44	5.05
MnO.....		.70
Alkalies.....	.50	
Loss on Ignition.....	.20	
		99.32

Blum (Ref. 3) has described the alteration of pyroxene to mica in the augites from Monroe Township, Orange county. The sides of the crystals are almost entirely covered with brown mica (clintonite), which is the same color as the augite. The mica plates have their cleavages in approximately parallel position. In one crystal only a core of the augite remained.

DETAILED ACCOUNT OF PYROXENE LOCALITIES.

Augites.

For convenience the occurrences are divided into the Adirondack Area and the Highland Region, under each of which heads the localities are arranged alphabetically.

I. THE ADIRONDACK AREA.

Adams Lake.—The writer feels some hesitation in describing this locality under the heading of New York State, for while there are a number of specimens in the Columbia University collection which are labeled "Adams Lake, N. Y.," there is also a crystal exactly like the others labeled "Adams Lake, Can.," and I am informed by Prof. F. D. Adams that there is a Canadian locality of this name, which is a bay of Lake Rideau, in lots 2, 3, 4 and 5, Ranges V and VI, N. Burgess township, Ontario.

The crystals are light green and $1\frac{1}{2}$ inches long, with smooth faces which are bright in places, but also show some uraltite. They are all doubly terminated. The combination of forms present in all is $a(100)$, $b(010)$, $m(110)$, $u(111)$, $s(111)$, $o(221)$, $c(001)$ and $p(\bar{1}01)$. (Pl. XVI, Fig. 7.) The dome $z(021)$ may occur. Both basal and orthopinacoidal partings are present.

Bonaparte Lake, Lewis Co.—There is one crystal in the collection of Columbia University which is said to come from this locality. It is exactly like those described from Adams Lake.

Cascadeville, Essex Co.—Granular pyroxene in a calcite vein is found on the mountain side above Long Pond, opposite the

hotel. The grains are rounded, transparent, of a light green color and many have a strong basal parting. No faces were found on them. An analysis of this material showed:

	Per cent.	Ratio.	Prop. parts.
SiO ₂	54.63	.9105	22
Al ₂ O ₃	5.26	.0513	1
FeO	3.00	.0416	1
CaO	22.63	.4041	10
MgO	14.18	.3545	9
	99.66		

The above analysis gives the formula $\text{Mg}_9\text{Ca}_{10}\text{Fe}_1\text{Al}_2\text{Si}_{22}\text{O}_{67}$, which may be considered as made up of FeSi_2O_6 , $\text{CaAl}_2\text{SiO}_6$, $\text{Mg}_9\text{Ca}_9\text{Si}_{19}\text{O}_{55}$. The latter corresponds closely to the diopside molecule $\text{MgCaSi}_2\text{O}_6$.

According to Beck (Ref. 2, 289),* green pyroxene crystals occur at this locality which show the combination $a(100)$, $b(010)$, $m(110)$, $c(001)$, $p(\bar{1}01)$, $o(\bar{2}21)$, $s(\bar{1}\bar{1}1)$, and $u(111)$. At the same place there is found a yellowish green or emerald green coccolite, which is translucent to semi-transparent. It is associated with grains of jet black pyroxene. The former is probably similar to the greenish granular pyroxenes in calcite from this locality in the collection of the New York State Museum.

DeLong's Mill.—Pyroxene of a dark color occurs in Hammond Township near DeLong's Mill (Ref. 2, p. 295), together with zircon, feldspar and apatite. The forms noted on it are $a(100)$, $b(010)$, $m(110)$, and $u(111)$. A grayish white and green variety, with a strong prismatic cleavage and pronounced basal parting, also occurs. A very incomplete analysis of it is given by Beck.

Diana, Lewis County.—There is an excellent section of a contact zone exposed on Ashmore's farm, near Natural Bridge. It is along the contact of the anorthosite and limestone, and is about two feet wide. The mineralogical structure of it is as follows: There is next to the gabbro and shading into it a layer containing abundant wollastonite. Next to this and towards the limestone is a second, though not sharply defined layer, containing a mixture of feldspar, scapolite, sphene and zircon. There then follows calcite with much pyroxene, and then coarse granular calcite,

*The Long Pond mentioned by Emmons (Geol. N. Y., 1837, p. 31) is the same locality as Cascadeville.

which passes into the normal limestone. The pyroxene in the limestone at the contact often shows well developed crystals. Graphite is common in the limestone.

The augite crystals from Diana are generally black or greenish black, and in section green. They have smooth, but dull faces. Doubly terminated specimens are not rare, and a basal parting is nearly always present. The ordinary combination of forms is $a(100)$, $b(010)$, $m(110)$, $u(111)$, $s(\bar{1}11)$, $o(\bar{2}21)$ and $z(021)$, (Pl. XVI., Fig. 6). Other combinations observed on crystals from this locality in the Columbia University, School of Mines collection are $m(110)$, $b(010)$, $c(001)$, $u(111)$, $o(\bar{2}21)$ and $s(\bar{1}11)$; $a(100)$, and $b(010)$ broad, $m(110)$ narrow, $c(001)$ broad, $e(011)$ narrow, and $u(111)$ small, (Pl. XVI., Fig. 1). The latter resembles the common Orange County form. A strong prismatic cleavage is sometimes present, and the crystals often reach a large size one in the School of Mines collection being five inches long, three inches thick, and with the forms $a(100)$, $b(010)$, $m(110)$, $c(001)$, and $o(\bar{2}21)$. It closely resembles the dark green augite from Russel.

The following combinations of forms from Diana are noted by L. C. Beck (Ref. 2) $m(110)$, $o(\bar{2}21)$, $v(221)$; $a(100)$, $m(110)$, $o(\bar{2}21)$; $a(100)$, $b(010)$, $m(110)$, $o(\bar{2}21)$; $a(100)$, $b(010)$, $m(110)$, $e(001)$, $u(111)$, $s(\bar{1}11)$; and $a(100)$, $m(110)$, $e(011)$, $v(221)$.

There is in the Root collection at Hamilton College, a light green crystal from Diana which has the forms $a(100)$, $b(010)$, $m(110)$, $p(\bar{1}01)$, $o(\bar{2}21)$, and $\lambda(\bar{3}31)$. (Pl. XV., Fig. 8). The crystal is twinned many times parallel to $c(011)$, and once parallel to $a(100)$, the twinning plane dividing it symmetrically. The similarity of this twin to those of fassaite from Monzoni in the Tyrol has been pointed out by G. v. Rath, (Ref. 41).

An analysis of the common dark green pyroxene from Diana gave

	Per cent.	Ratio.	Prop. parts.
SiO ₂	53.97	.8995	290
FeO	8.63	.1198	39
CaO	23.96	.4278	133
MgO	7.32	.1830	60
Al ₂ O ₃	4.94	.0482	15
Fe ₂ O ₃	0.50	.0031	1
	99.33		

Sp. Gr. 3.36

This gives Ca₁₃₃Mg₆₀Fe₃₉Fe₂Al₃₀Si₂₉₀O₈₄₀

or	39 (CaFeSi ₂ O ₆)
	15 (Al ₂ Si ₃ O ₉)
	60 (CaMgSi ₂ O ₆)
	CaFe ₂ SiO ₆
	33 (CaSiO ₃)

leaving Si₁₂O₂₆, which is approximately SiO₂.

C:ε	41° 30'
a	1.6888
β	1.6932
γ	1.7108
γ—a	.022
2W*	79° 27'
2V	60° 40'

Gouverneur, St. Lawrence Co.—Bright gray and dark green pyroxene occurs associated with hornblende in the limestone one mile southeast of Gouverneur (Ref. 2, p. 295). A flat crystal tabular parallel to *b*(010) is figured by Prof. S. L. Penfield in Dana's System of Mineralogy, 1893. The forms on it are *a*(100), *b*(010), *m*(110), *c*(001), *u*(111), *v*(221) and Δ ($\bar{3}11$).

Augite in rounded masses and with an extinction angle of 40° occurs in the schist underlying the limestones at Gouverneur. In the gneisses the pyroxene in section is pale and colorless and has an extinction of 45°. It shows a certain amount of alteration to chlorite, but changes mostly to uraltite. Pyroxenic phases of the limestone are not uncommon, the latter containing colorless grains of pyroxene with a high extinction angle (Ref. 48).

The dark green crystals which the writer has seen from this locality are usually of prismatic habit and without terminations. One form in the Collection of the School of Mines, Columbia University, shows *a*(100), *b*(010), *c*(001), with *u*(111), and *s*($\bar{1}11$), very small (Pl. XIV., Fig. 4). A white and much decomposed crystal in the same collection has the planes *a*(100), *b*(010), *m*(110), *c*(001), and *u*(111). (Pl. XVI., Fig 4).

Hammondville, Essex Co.—There is a small black crystal with smooth dull faces from this locality in the collection of Cornell University. (Pl. XIV., Fig. 1). The planes noted on it are *m*(110), and *b*(010) broad, *a*(100) narrow, and the terminal faces are *c*(001), and *s*($\bar{1}11$). The crystal is a very well formed one considering its occurrence with magnetite. The sp. gr. is 3.5.

Black pyroxene associated with magnetite occurs on the shore

* 2W = in H₂O.

of Crag Harbor near Port Henry, and is said to occur in regular grains and imperfect crystals, (Ref. 21).

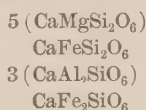
Keene, Essex Co.—Black pyroxene in calcite is found at the Weston Mine two miles southwest of Keene. The mineral occurs intermixed with the ore, and also in streaks along the edges of the ore bed. When surrounded by calcite the pyroxene often develops well bounded crystals, the ordinary form being $a(100)$, $b(010)$, $m(110)$, and $c(001)$. One small crystal had the combination $a(100)$, $b(010)$, $m(110)$, $s(\bar{1}10)$, and $o(\bar{2}21)$. (Pl. XVI., Fig 2). Most of the crystals are decomposed and in section sometimes show an abundant deposition of magnetite grains along the cleavage lines. In section the augite is slightly pleochroic, the colors being green to yellow. It also exhibits an intimate association with garnet, which may perhaps be an alternation product of it. (Ref. 26).

An analysis of the fresher portion of the material gave

	Percentage.	Ratio.	Prop. parts.
SiO ₂	56.00	.933	32
FeO	2.40	.034	1
CaO	21.63	.386	13
MgO ..	5.23	.1307	5
Fe ₂ O ₃	4.70	.029	1
Al ₂ O ₃	8.44	.082	3
Alkalies.....	.50		
Ignition.....	.20		
	99.10		

Sp. Gr. 3.5

From the above we obtain the formula $Ca_{13}Mg_5Fe_1\ddot{Fe}_2Al_6Si_{32}O_{95}$, which is resolvable into



leaving $Si_{12}O_{26}$, which is approximately SiO₂.

Keene, Essex Co.—Dark green prismatic grains of augite are abundant in the limestone near Keene. Their composition is

	Percentage.	Ratio.	Prop. Parts.
SiO ₂	56.14	.935	467
FeO.....	2.85	.039	19
Fe ₂ O ₃	.38	.002	1
Al ₂ O ₃	8.19	.080	40
CaO.....	17.79	.31	150
MgO.....	13.67	.34	170
	99.02		

Lyon Mountain, Clinton Co.—The Bostonite dikes near Lyon Mountain contain augite associated with plagioclase and olivine. The augite occurs in irregular grains or idiomorphic crystals, showing $a(100)$, $b(010)$, and $m(110)$. It is usually of a rose tint and shows slight pleochroism. The large, well-formed crystals show a decomposed granular core, and alteration to chlorite is not uncommon. The extinction is about 45° (Ref. 15).

Mt. Marcy, Essex Co.—Diallage is said to occur in broadly foliated dark green masses in the gabbros of Mt. Marcy (Ref. 30). The composition of it is:

	Per cent.	Ratio.	Prop. parts.
SiO ₂	46.28	.7811	56
TiO ₂	.59		
FeO	14.80	.2055	15
CaO	18.78	.3353	24
MgO	8.91	.2227	16
Fe ₂ O ₃	2.21	.0138	1
Al ₂ O ₃	7.38	.0720	5
H ₂ O	1.115		
	100.065		

Sp. Gr. 3.386

This calculated, gives the formula,



This can not be resolved into a mixture of isomorphous silicates, and it seems therefore more reasonable to consider the ferric iron and alumina to be present as oxides, and we therefore get



The pyroxene formula can then be resolved into the following metasilicates:



Natural Bridge, Lewis County.—The pyroxenes from this locality are generally embedded in calcite. As Natural Bridge lies almost on the boundary line between Lewis and Diana Townships, it is probable that many of the crystals labeled "Diana" come from the former locality.

A number of augite crystals were collected by the writer at

Natural Bridge, but none of them showed any good terminal faces. The faces of the prismatic zone were usually easily recognizable and smooth. The crystals are dark green to black. Only three specimens have been found in the collections examined, which were labeled as having come from this locality. One is a group of grayish black crystals in the collection of Hamilton College, showing the forms $a(100)$, $b(010)$ narrow, $m(110)$ large, $u(111)$, $o(\bar{2}21)$ and $s(\bar{1}11)$ small. (Pl. XV, Fig. 9.) The pyramidal faces are etched with longitudinal interrupted striations, those on $u(111)$ being parallel to $a(100)$, while those on $o(221)$ are parallel to $b(010)$. The other two specimens above mentioned are single crystals in the collection of Columbia University, School of Mines. They are black with a greenish coating, and doubly terminated. The combination of forms noted on both is $a(100)$ and $b(010)$ very narrow, $m(110)$ large, $u(111)$, $s(\bar{1}11)$, $o(221)$ and $z(021)$ very small. These crystals are very like the form usually labeled as having come from Diana.

Oxbow, Jefferson Co.—Pyroxene occurs on the shore of Vrooman's Lake (Ref. 2, p. 290), near Oxbow. It is of a green color and associated with crystallized mica. The forms recorded are $a(100)$, $b(010)$ narrow, $m(110)$ broad, $c(001)$, and $s(\bar{1}11)$. The only specimen which the writer has seen from this locality is in the Root Collection at Hamilton College. The crystals are similar to those described by Beck and show the planes $a(100)$, $b(010)$, $m(110)$, $u(111)$, $s(\bar{1}11)$, and $o(221)$.

Pitcairn, St. Lawrence Co.—The green augites from this locality have bright prismatic faces and striated terminal ones. The crystals occur singly or in clusters and are invariably intergrown with microcline and albite.* A prismatic cleavage and basal parting are generally present, though the former is only seen in thin sections. The crystals are mostly two to three inches long and about an inch thick. Doubly terminated individuals are not rare, and a common habit is a flattening parallel to $b(010)$. The terminal faces are always covered with interrupted striae. The most general combination of forms is $a(100)$, $b(010)$, $m(110)$, $u(111)$, $s(111)$, and $o(221)$ (Pl. XIII, Fig. 7). The basal pinacoid $c(001)$ is not uncommon, and $p(101)$ was noticed on one specimen in the Columbia University collection. Another

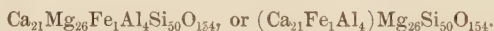
*L. M. Luquer, School of Mines Quarterly, XIV, p. 328.

combination of forms is $m(110)$, $b(010)$, $c(001)$, $u(\bar{1}11)$, $o(221)$, and $s(\bar{1}11)$.

A second variety in the same collection is a cluster of very small glassy crystals of a grayish white color. They are $\frac{1}{3}$ – $\frac{1}{2}$ in. long, with the ends rounded, but the faces in the prismatic zone are $a(100)$, $m(110)$, $b(010)$. An analysis of the common green variety gave:

	Percentage.	Ratio.	Prop. parts.
SiO ₂	54.57	.9061	50
FeO	1.301	.018	1
CaO	21.42	.3825	21
MgO	18.56	.464	26
Al ₂ O ₃	3.09	.0302	2
Alkalies	.40		
Ignition	.15		
	99.39		

From the above we obtain the formula



This is close to diopside in composition but, on account of the high percentage of alumina is placed under augite.

Sp. Gr. 3.20.

C: c	41° 30'
	Na.
α	1.6306
β	1.6843
γ	1.7036
$\gamma - \alpha$	.0230
2H	78° 57'
2V	59° 40'

Port Henry, Essex County.—Pyroxene of a jet black color occurs in close association with the magnetite at this locality. Massive and granular specimens are not uncommon, but crystals are rare. There is a fine group of crystals in the collection of Prof. Kemp, which were found in the Cheever mine at Mineville, four miles northwest of Port Henry. The pyroxene is associated with granular magnetite and labradorite, and occurs on the edge of the orebody. When it is intergrown with the magnetite it shows no crystal faces, but when surrounded by the feldspar well developed ones occur. The crystals (Pl. XIV, Fig. 8) are about half an inch long and nearly the same thickness. In the pris-

matic zone are a (100), b (010) and m (110) equally developed, but the latter may become so narrow as to give the crystal a square appearance. The terminal faces are u (111) and s (111), the latter often so extended as intersect the front prism faces. A basal parting is sometimes present as well as a lamellar structure. The crystals have smooth but dull faces and are emerald green in the thinnest sections. They show a strong pleochroism. $C:\epsilon$ is 52° and the specific gravity is 3.60.

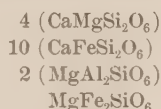
A section thin enough to measure the angle of the optic axes could not be obtained, as the material is so opaque, nor could any determinations be made of the indices of refraction by the Kohlrausch method, even with using phenylsulphide.

The composition of this black augite is:

	Percentage.	Ratio.	Prop. parts.
SiO ₂	49.12	.8186	37
FeO	15.98	.2220	10
CaO	17.30	.309	14
MgO	6.06	.151	7
Fe ₂ O ₃	3.53	.0220	1
Al ₂ O ₃	7.49	.0731	4
	99.48		

Sp. Gr. 3.60.

From this analysis we obtain the formula $\text{Ca}_{14}\text{Mg}_7\text{Fe}_{10}\text{Fe}_2\text{Al}_4\text{Si}_{37}\text{O}_{117}$ or



leaving Si_6O_{15} , which is approximately SiO_2

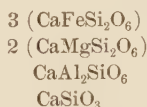
Rogers Rock, Essex Co.—A greenish gray variety of augite of slender prismatic form with the planes a , b and sometimes m is found at this locality (Ref. 2). One specimen was 7–8 inches long and of proportionate diameter. The crystals which are rarely well formed are associated with feldspar and titanite. They are sometimes intergrown with the latter.

An analysis of this augite by Seybert (Ref. 45) gave

	Percentage.	Ratio.	Prop. parts.
SiO ₂	52.66	.8676	14
FeO	12.30	.1708	3
CaO	23.33	.4166	7

	Percentage.	Ratio.	Prop. parts.
MgO	5.73	.0932	2
Al ₂ O ₃	6.66	.065	1
H ₂ O	.33		
MnO	tr		
	101.01		

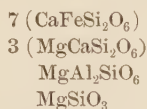
This gives Ca₇Mg₂Fe₃Al₂Si₁₄O₄₃ or approximately



A brown and black granular pyroxene is associated with the crystallized material and the composition of this as analyzed by the same author was found to be

	Percentage.	Ratio.	Prop. parts.
SiO ₂	51.00	.85	22
FeO	14.43	.20	7
CaO	23.00	.4107	10
MgO	6.26	.1545	5
Al ₂ O ₃	3.00	.0293	1
H ₂ O	.66		
MnO	tr		
	98.35		

This gives Ca₁₀Mg₅Fe₇Al₂Si₂₂O₆₉ or approximately



Rossie, St. Lawrence Co.—Most of the individuals from this locality are large green crystals, with smooth dull faces and glassy interior. Those specimens in the collections of Columbia University have evidently come from a vein in the anorthosite at its contact with the limestone. Most of the crystals exhibit the common basal parting, and the combination of faces observed on all is *a* (100), *b* (010), *m* (110), *u* (111), *o* ($\bar{2}21$), and *s* ($\bar{1}11$); *c* (001), also occurs on some. One figured by Prof. Penfield in Dana's System of Mineralogy shows *a* (100), *b* (010), *m* (110), *u* (111) and *o* (221). (Pl. XVI., Fig. 5).

Prof. G. H. Williams has described a crystal of pyroxene collected at Grassy Lake near Rossie, (Ref. 58), and which is now

in the collection of the National Museum at Washington. It is $3\frac{1}{2}$ inches long, and perfectly formed. The interesting feature about it is the hemihedral distribution of the planes. At the upper end are the planes $u(111)$ very large, $s(\bar{1}11)$ and $o(\bar{2}21)$, at the lower end $p(101)$, $c(001)$, $u(111)$ small, $s(111)$ and $o(\bar{2}21)$. In the prismatic zone are $a(100)$, $b(010)$, $m(110)$. On Pl. XIV., Fig. 2 there is given a drawing of this crystal copied from Prof. William's paper.

Russel, St. Lawrence Co.—Many of the forms from Russel are stout greenish black often doubly terminated individuals, of variable size. They have moderately smooth prismatic faces, but much pitted terminal ones. The ordinary combination of planes is $a(100)$, $b(010)$, $m(110)$, $p(101)$ and $u(111)$ (Pl. XV., Fig. 7); $o(\bar{2}21)$, was seen on one specimen. This same form of crystal is sometimes labeled Pierrepont. A parting parallel to $a(100)$ and $c(001)$ is present. One form in the Columbia University collection is very flat parallel to $b(010)$ and shows only the planes $b(010)$ and $m(110)$. (Pl. XIII., Fig. 3). It is much decomposed.

Thousand Islands.—Many of the diabase dikes of these islands contain augite, which in section is of a brownish pink color, with faint pleochroism. The prismatic cleavage is pronounced and twinning abundant. The augite alters to pale green chlorite or to a yellowish brown aggregate resembling serpentine. (Ref. 50.)

Chilson Hill, Ticonderoga, Essex Co.—The rock at this locality is a gneiss containing much calcite. The minerals found in the former are scapolite, quartz, graphite, apatite, titanite and pyroxene. These latter which have been described by F. L. Nason (Ref. 39), are peculiar on account of the large size of the crystals, and the inclusions which they carry. Two specimens in the collection of the New York State Museum at Albany are said to be the largest ever found in the State and perhaps in the world. The larger of the two measures 36 inches in circumference and is 18 inches long, and weighs over 100 pounds, while the second is 18 inches in circumference and 12 inches long. The faces present are $a(100)$, $b(010)$ and $m(110)$, all equally developed. There are no terminal faces, the flat ends of the crystals being due to parting planes. The crystals are commonly lamellar and badly decomposed, and the faces are roughened by numerous small interrupted striæ. Calcite often penetrates the crystals and together with quartz often forms rounded included masses. Graph-

ite is also a common associate and scales of it deeply penetrate the crystals.

The gabbros of the eastern Adirondacks contain a green augite in great abundance. Deep pink garnets occur in close association with it and the same cracks often traverse both minerals. As has been already mentioned the garnet is probably an alternation product. Reaction rims of hornblende around the augite often separate it from the feldspar. (Ref. 29). Interstitial alio-trimorphic augite occurs in the diabase dikes, south of Port Kent, Essex Co., (Ref. 24), and also in the diabase, lamprophyre and camptonite dikes of Willsboro and Essex township of Essex Co., (Ref. 54).

2. THE HIGHLAND^F AREA.

Bradley Mines, Monroe Township, Orange Co.—These mines are about three miles northeast of Arden. The bed of magnetite is cut by a diorite and porphyry dike. Associated with the ore are large quantities of calcite enclosing crystals of magnetite, apatite, augite and titanite, as well as some pyrrhotite. The augite is in granular masses or in short, stout crystals of a dark green color. They all show the planes $a(100)$, $b(010)$, and $m(110)$ in the prismatic zone, but the terminal faces are too rounded to admit of positive identification.

Coldspring, Putnam Co.—Beck (Ref. 2, p. 294) states the occurrence of pyroxene at this locality, but gives no further information about it.

Greenwood Furnace, Orange Co.—This is another indefinite locality. There are no mines or mineral localities at the former site of Greenwood Furnace, now called Arden, and most of the ore used was obtained from the Oneil Mine, which has furnished an abundance and variety of mineralogical specimens in past years, so that the crystals labeled Greenwood Furnace very probably came from there. There is also a possibility of their having come from the Bradley Mines, in Woodbury Township, about three miles northeast of the old Greenwood Furnace.

Beck (Ref. 2) states, however, that pyroxene associated with crystallized mica has been found one-half mile east of Greenwood Furnace. It is green, gray-green and ash-gray. The combination of forms are $a(100)$, $m(110)$, $e(011)$; $a(100)$, $m(110)$, $e(011)$, $c(001)$; $a(100)$, $b(010)$, $m(110)$, $c(001)$; $a(100)$, $b(010)$,

$e(011)$, $\sigma(001)$, $p(101)$. One crystal found was 6 in. long and 10 in. in circumference.

There are a number of specimens in the collection of the New York State Museum which have the usual habit of Orange County crystals, with the faces $a(100)$, $b(010)$, $m(110)$, $c(001)$, and $e(011)$.

The specimens in the Columbia University collection are short, stout greenish black crystals, of the combination $a(100)$, $b(010)$, $m(110)$, $c(001)$, and $s(111)$. One fresh piece was found which in section gave an extinction of $42^\circ 40'$. This is very close to that recorded by Doelter (Ref. 14). The color in section was light green.

Doelter has described some augites from Greenwood Furnace (Ref. 14), in which the extinction on $b(010)$ was $42^\circ 20'$ and on $m(110)$ $31^\circ 50'$. The crystals were prismatic individuals with their faces somewhat roughened by alteration, but the light green interior portion of them was perfectly fresh. The composition of this latter portion was:

SiO ₂	49.18
FeO.....	2.55
CaO.....	20.62
MgO.....	16.83
Fe ₂ O ₃	5.05
Al ₂ O ₃	5.09

99.52

Sp. Gr. 3.295.

The above calculated gives a formula $\text{Si}_{47}\text{Ca}_{21}\text{Mg}_{24}\text{Al}_3\ddot{\text{Fe}}_2\text{Fe}_2\text{O}_{156}$, which Doelter considers as consisting of the following silicates:

19 (MgO, CaO, 2 SiO ₂)
2 (CaO, FeO, 2 SiO ₂)
2 (Fe ₂ O ₃ , MgO, SiO ₂)
3 (Al ₂ O ₃ , MgO, SiO ₂)

He then points out that $\text{Ca}:\text{Mg}:\text{Fe}::.368:.420:.035$ or as 11.5:12:1, hence $\text{Ca}<\text{Mg}+\text{Fe}$, as he claims is the case with augites.

Highland Township, Orange Co.—Granular pyroxene is not uncommon around many of the small ore bodies found in the township.

There is one specimen of granular augite in the Columbia

University collection, from West Point. The exact location is unknown. It very closely resembles that found with the ore near the Weston mine in Essex County.

Highlands, Putnam Co.—Pyroxene occurs associated with amphibole and titanite at the pyrite mines on the east side of Anthony's nose. The writer found one large decomposed crystal, with prismatic faces and a lamellar structure caused by basal parting.

A large stout augite crystal, much decomposed and bearing the label "Highlands of the Hudson," is in the Cornell University collection. It has the common habit of Orange county crystals, with the combination of forms $a(100)$, $b(010)$, $m(110)$, $c(001)$ and $e(011)$, (Pl. XIV, Fig. 5). Attached to it are several smaller ones with the planes $s(\bar{1}11)$ and $u(111)$.

A fine black doubly terminated crystal of the form shown in Pl. XV, Fig. 3, and labeled "Orange Co.," is in the Williams College collection.

Monroe Township, Orange Co.—It is unfortunate that the term Monroe on many pyroxene labels indicates nothing more definite than Monroe township, for there are several localities within the township where pyroxene occurs, and when the term is found on labels of specimens which were collected over five years ago, it may also refer to localities within the townships of Tuxedo and Woodbury, which were formerly included in Monroe township. In the present township the two localities which have furnished most of the pyroxene specimens are the Oneil and the Clove Iron mines, both southeast of Monroe village.

The majority of the pyroxene crystals which the writer has seen from this township are large black or greenish black individuals, with dull roughened faces and more or less decomposed. One of the best specimens is in the collection of Cornell University. It is a black doubly terminated crystal, about $1\frac{1}{4}$ in. long, and $\frac{3}{4}$ in. thick. The faces present are $a(100)$, $b(010)$, $m(110)$, $u(111)$, $s(\bar{1}11)$, $o(221)$ and $p(101)$ (Pl. XIII, Fig. 2). The faces in the prism zone have an almost submetallic lustre and are striated with lines parallel to the base, which probably represent parting planes.

Another group of black crystals in the same collection shows the forms $a(100)$, $b(010)$, $m(110)$, $c(001)$ and $e(011)$. (Pl. III, Fig. 3). This combination is a very common one in Orange

county. The crystals of this group vary in length from a fraction of an inch to several inches. The base is often very narrow. Still another specimen from Monroe township in the same collection shows the combination $a(100)$, $b(010)$, $m(110)$, $u(111)$, $s(\bar{1}11)$, $o(\bar{2}21)$ and $z(021)$, the latter very small, (Pl. XIII., Fig. 5).

There is in the Columbia University collection a single crystal from Monroe township. It is black with rough faces and about an inch long. It is tabular parallel to $a(100)$ and shows the forms $a(100)$, $b(010)$, $m(110)$ and $e(011)$, (Pl. XV, Fig. 1). Growing out of one end is a smaller crystal of the same form and habit, the axes of the two being parallel. The larger individual is twinned parallel to $a(100)$, but the smaller one is not.

Montrose, Westchester Co.—A gray or red augite associated with plagioclase occurs in the gabbros of the Cortlandt Series south of Peekskill. (Ref. 57 and 59). Both colors often appear in the same individual. The mineral shows no pleochroism, but frequently has a strong orthopinacoidal parting, and the metamorphism which the rock has undergone has often produced a peripheral granulation of the augite. The diorites of this region show excellent examples of the passage of pyroxene to compact brown hornblende.

The limestone around the Cortland area often contain a granular lime bearing pyroxene along and the near contact, and green pyroxene is similarly developed in the limestones at Stony Point on the West Shore Railroad. It is here associated with light green hornblende, zoisite, titanite, and much scapolite.

Rosetown, Rockland Co.—Green augite is a common constituent of the diorites near this locality (Ref. 22). It is closely associated with less basic hornblende which was formed before it. An analysis of this augite made by Prof. Kemp gave:

	Percentage.	Ratio.	Prop. parts.
SiO ₂	46.00	.76	10
Al ₂ O ₃	14.80	.134	2
Fe ₂ O ₃	11.20	.07	1
MgO.....	4.75	.119	2
CaO.....	15.52	.277	4
Na ₂ O.....	3.20		
K ₂ O.....	4.70		
	100.17		

Tuxedo Township, Orange Co.—At the Sterling Iron Mines

dark green granular pyroxene is abundant, associated with hornblende, epidote, red and white feldspar, biotite and tourmaline. Much of the gneiss in the vicinity of the orebody is pyroxenic.

Tilly Foster, Putnam Co.—Although many mineral species have been described from the Tilly Foster Iron Mines, pyroxene has not yet been recorded from there. It is not common however. There is one group of small crystals in the collection of Columbia University.

The crystals are about $\frac{1}{4}$ inch long, green and transparent, with smooth faces. Some show a basal parting. The general combination of planes is $a(100)$ and $b(010)$ narrow, $m(110)$ broad, $c(001)$ large, $u(111)$, and $s(111)$, the latter so extended as to intersect the front prism faces (Pl. XIV, Fig. 12). The crystals are embedded in calcite.

A second and unique specimen is in the collection of Mr. F. L. Nason, of New Brunswick, N. J. It is a single individual about $\frac{3}{4}$ inch long and $\frac{1}{4}$ inch thick, and tabular parallel to $b(010)$. There are terminal faces at one end, but the other is broken off. The planes of the prismatic zone are smooth and bright, while the terminal ones are slightly pitted. The combination of forms is $a(100)$, $b(010)$, $m(110)$, $f(310)$, $o(221)$ and $p(\bar{1}01)$ (Pl. 1, Fig. 1.) A very small dome face probably $e(011)$ is present. The orthoprism $f(310)$ is very narrow and is of interest as it is not known to occur on any other pyroxene from this State. It was determined with the reflection goniometer.

The extinction as measured through the transparent crystal is $41^{\circ}11'$.

Sp. Gr. 3.6

There have been recently added to the Columbia University collection some large crystals from this locality. The largest is a prismatic individual about two inches long and without terminations. It is permeated throughout with grains of pyrrhotite. Another but well-formed crystal, is about one inch long, $\frac{7}{8}$ inch broad and $1\frac{1}{2}$ inch thick. The faces are smooth and fairly bright in places. A strong basal parting is present and the crystal is slightly tabular parallel to $b(010)$. There is also an abundant deposition of fine grains of pyrrhotite along the parting planes. The following combination of forms occurs on this crystal and nearly all the smaller ones found attached to it. $a(100)$, $b(010)$ broad, $m(101)$, $c(001)$ small, $p(\bar{1}01)$ very large, $u(111)$ small,

s(111) long and narrow, and *o*(221) small, (Pl. IV, Fig. 9.). *z*(021) was noticed on the large crystal, but the face is a very small triangular one. The small crystals are often transparent and exhibited a beautiful green color similar to the one in Mr. Nason's collection.

The pyroxene at Tilly Foster is associated with a large lenticular bed of magnetite occurring in the gray gneiss. In the lower portion of the orebody is a great mass of massive hornblende rock. The associated minerals are serpentine, chondrodite, fluorite, garnet, pyrrhotite, amphibole, ripidolite, tourmaline and calcite.

Two Ponds, Monroe township, Orange Co.—Beck states that pyroxene of a gray-green, green or brown color occurs in limestone at Two Ponds, (Ref. 2, p. 291). It is associated with titanite, zircon and scapolite and is both massive and crystallized. The crystals are usually only prismatic with rough ends, but other combinations are *a*(100), *m*(110), *b*(010) and *e*(011); *a*(100), *m*(110), *b*(010), *c*(100) and *p*($\bar{1}01$); and *m*(110), *p*($\bar{1}01$), *c*(001).

Warwick Township, Orange Co.—Pyroxene is very abundant, near Edenville and Amity, and around Mts. Adam and Eve, a short distance to the north. It occurs either in the contact zones between the granite and the limestone or else disseminated through the latter at some distance from the contact. The conditions in passing from the granite to the limestones are as follows: (Ref. 23) Near the contact the granite either becomes an aggregate of green pyroxene and scapolite or a granite like zone formed of the two is present. The limestone near the contact is also charged with silicates in bunches or scattered through it. These bunches are composed chiefly of brownish-green hornblende, dark brown biotite or phlogopite, green pyroxene, (light green in section), titanite, pyrite, calcite and some scapolite. Chondrodite is also present sometimes and with it spinel. At one locality where the granite and limestone are in actual contact, the former contains pyroxene and scapolite and the latter coarsely crystalline calcite and phlogopite. Fifteen feet from the contact the granite has green pyroxene associated with quartz and microcline. On the southwest side of Mt. Adam, the scapolite zone contains large prisms of scapolite and pyroxene, the latter about half an inch in diameter and often several inches long. The

presence of fluorite, chondrodite and warwickite indicate mineralizers.

The pyroxene crystals occurring in the scapolite zone are dark green, and in section light green. The faces of the prismatic zone are a (100), b (010) and m (110), equally developed; they are smooth, but dull. As a rule terminal faces are rare, but when present the usual combination of forms is u (111), o (221), s (111), c (001) and p (101). The greater development of p (101) over c (001) is a characteristic feature of these crystals. A basal parting due to twinning is often apparent, especially in sections, and a prismatic cleavage is not rare, but likewise is often only to be seen in sections.

Pl. II, Fig. 7, shows the prismatic form and Pl. II, Fig. 6, the terminated form of these pyroxenes.

The composition of this dark green augite is :

	Percentage.	Ratio.	Prop. parts.
SiO ₂	52.01	.866	206
FeO	6.86	.094	22
CaO	26.90	.480	100
MgO	11.26	.281	70
Fe ₂ O ₃	.67	.0042	1
Al ₂ O ₃	5.82	.0568	14
Alkalies.....	.50		
	99.92		

Sp. Gr. 3.6.

The formula obtained from the analysis is Ca₁₀₀, Mg₇₀, Fe₂₂, Fe₂, Al₂₈, Si₂₀₆, O₆₄₉, or

22 (Ca Fe Si₂O₆).

Mg Fe₂ SiO₆:

11 (Ca Al₂ SiO₆).

3 (Mg Al₂ SiO₆).

66 (Ca Mg Si₂O₆).

$c : a = 45^{\circ} 15'$

Beck (Ref. 2) mentions the occurrence, one mile northwest of Edenville, of dark green or black crystals of pyroxene associated with apatite, hornblende, titanite and calcite. A form is also said to occur at Warwick Mountain, which has the forms a (100), b (010), m (110), c (001) and e (011).

This same township, Warwick, has furnished the well-known tabular crystals of Leucagite which have attracted so much

attention among mineralogists. Beck (Ref. 2) gives their occurrence as $2\frac{1}{2}$ miles north of Edenville. The crystals are yellowish gray and have roughened faces. They are broadly flattened parallel to $c(001)$ and show striations parallel to the base. In describing them Beck mistook the base for the orthopinacoid. The usual form of the Leucaugite is a combination of $a(100)$, $b(010)$, $m(110)$, $c(001)$, $u(111)$, $s(111)$ and $o(221)$ (Pl. XIV, Fig. 1). G. V. Rath mentions a twin crystal (Ref. 39) of more prismatic habit, formed according to the common law, and which has the orthodome $p(101)$ in addition to the above mentioned faces. The striations parallel to $c(001)$ were at first considered by him to be due to irregularities of growth, but he subsequently correctly ascribed them to twinning. He also notes the surface alteration of these crystals to amphibole.

These tabular forms were also described by Des Cloiseaux (Ref. 12) who figured one with a hemihedral development in the direction of the vertical axis, there being at one end the forms $p(101)$, $s(111)$, $o(221)$, $e(011)$ and $u(121)$ and at the other end $p(\bar{1}01)$, $u(111)$ and $a(312)$.

Prof. G. H. Williams has described a crystal from the Root collection which was of the usual habit with the forms, $c(001)$, $u(111)$, $s(\bar{1}11)$, $o(\bar{2}21)$, $m(110)$, $b(010)$, $a(100)$, but below, toward the front, there was only $o(221)$ and $p(101)$, showing it to be hemihedral in the direction of the vertical axis. The lower back quarter is just like the front but reversed so that the lower half is a twin (Pl. XIV, Fig. 3).

The ordinary tabular form is to be seen in nearly every large collection. The Leucaugite also occurs in white granular masses in calcite as represented by several specimens in the collection of Columbia University.

Other specimens in the same collection and from Warwick township are a red-brown granular pyroxene from Amity, and a greenish-gray cleavage specimen with numerous small scales of graphite scattered through it.

Beck, (Ref. 2), notes a black pyroxene from Rocky Hill near Warwick. Specimens probably from this locality are in the Columbia University collection. They are small interlacing prismatic individuals about two-thirds of an inch long. A few of them show terminal faces probably unit pyramids, but they are too rounded for determination.

Much of the serpentine found at Amity may result from the alternation of pyroxene. (Ref. 33).

Several analyses of pyroxenes from Edenville have been published, but little information is given concerning the material from which they are made, or the exact locality. One of these is an analysis of pyroxene from Edenville, by Brewer, as follows (Ref. 4):

	Percentage.	Ratio.	Prop. parts.
SiO ₂	36.94	.615	19
FeO.....	36.03	.109	14
CaO.....	12.71	.227	17
MnO	2.24	.0312	1
Al ₂ O ₃	11.22	.109	4
	99.14		

This analysis gives

Ca₇Fe₄MnAl₃Si₁₉O₆ which we may consider as a mixture of

4(CaFeSi₂O₆)

3(CaAl₂SiO₆)

Al₂Si₃O₉

leaving MnSi₅O₁₁ or approximately Mn₂Si₂O₆+3SiO₂

LEUCAUGITE.

Amity, Orange Co. Leucaugite of light brown color occurs in grains or rounded crystals, associated with calcite and sebertite, and is identical with leucaugite from Bathurst, W. Canada, (Ref. 31.)

	Percentage.	Ratio.	Prop. parts.
SiO ₂	50.05	.834	238
CaO.	25.63	.458	131
Mgo	14.48	.362	103
Fe ₂ O ₃	.56	.0035	1
Al ₃ O ₂	7.16	.07	20
H ₂ O	1.66		
	99.54		

Sp. Gr. 3.26

From this analysis we obtain the formula

Ca₁₃₁Mg₁₀₃Fe₂Al₄₀Si₂₃₈O₇₇₃ which is made up of

MgFe₂SiO₆

20(CaAl₂SiO₆)

Mg₁₀₂Ca₁₁₁Si₂₁₆O₆₄₇

the latter being approximately MgCaSi₂O₆

The dolomitic limestones of Westchester, Dutchess and New York Counties often contain crystals of white pyroxene in great

abundance. These are almost invariably of the same habit, with a strong flattening parallel to the orthopinacoid. They occur as single individuals in zones or sometimes as Mr. F. L. Nason informs me, in rounded masses. The crystals are colorless to milkwhite and translucent to opaque. They might, perhaps, be classed with the diopsides judging from the appearance of some, but the higher percentage of alumina classes them with augite, and it seems to the writer that the variety name of Leucaugite may be appropriately applied to them.

Sing Sing, Westchester Co.—The usual combination of forms is $a(100)$, $b(010)$, $m(110)$, $v(221)$, and $o(\bar{2}21)$ (Pl. XV, Fig. 4) less commonly $c(001)$; $p.(101)$ is very rare and was noted on one specimen in the collection of Columbia University. $u(111)$ is equally rare. In rare cases $a(100)$ and $b(010)$ are wanting or are very narrow, so that the crystal has a square appearance. One specimen in the same collection shows $v(221)$ but not $o(221)$, (Pl. XV, Fig. 2.)

A strong basal and orthopinacoidal parting, both due to twinning are present, but the latter is rare. The crystals are frequently superficially altered to tremolite, and nearly all are stained exteriorly with limonite. The prison quarry has yielded the best specimens in former years, but very few are found now. There is a granite dike cutting the limestone a few hundred feet south of the quarry, but there is no evidence to show that the crystals are the result of contact action.

An analysis was made of some nearly transparent pieces of a crystal from Sing Sing, with the following results:

	Percentage.	Ratio.	Prop. parts.
SiO ₂	53.30	.8883	80
FeO	.80	.0111	1
CaO	24.82	.4432	40
MgO	16.18	.4045	36
Al ₂ O ₃	4.11	.0401	4
H ₂ O	.15		
	99.36		

Sp. Gr. 3.18, Ries.
3.10, Beck.

The above calculated gives Ca₄₀Mg₃₆Fe₁Al₈Si₈₀O₂₄₉ or approximately,

	Ca Fe Si ₂ O ₆ .
	4 (Ca Al ₂ SiO ₆).
	35 (Ca MgSi ₂ O ₆).
	Mg SiO ₃ .
C: f.	40°
<i>a</i>	1.6778
<i>β</i>	1.6848 Na.
<i>γ</i>	1.7025
<i>γ</i> — <i>a</i>	.0247
2 W	= 75° 50'
2 V	= 59°

Kingsbridge, New York Co.—Most of the crystals from the dolomite are considerably decomposed and replaced by granular dolomite. They resemble the Sing Sing specimens exactly. There is one exceptionally large one in the Columbia University collection. It is four inches long and two inches wide and has a smaller one penetrating it.

Paterson, Dutchess Co.—The quarries northwest of the station have furnished a considerable number of these tabular leucaugites. Mr. Nason has in his collection a fine group of small glassy crystals from this locality. They show the usual combination, *a* (100), *b* (010), *m* (110), *v* (231), *o* (221) *c* (001), and *p* (101).

According to Beck (Ref. 2) crystals twinned parallel to both *a* and *b* (010) have been found in Knapp's quarry, at Paterson. The crystals often have the granular structure of the dolomite, and are sometimes broken into several pieces, the dolomite filling in the breaks.

Phillipstown, Putnam Co.—According to Beck (Ref. 2) white pyroxene has been found on the Hustis farm. It is translucent and sometimes light green. Serpentine and pale green apatite are occasionally associated with it.

HUDSONITE (HEDENBERGITE?)

West Point, Orange Co.—A black lamellar variety of pyroxene associated with quartz, black or bronze mica, and feldspar occurs on the west bank of the Hudson river about three miles above West Point. A specimen analyzed by Vanuxem, (Ref. 53) gave:

	Percentage.	Ratio.	Prop. parts.
SiO ₂	51.00	.850	25
CaO.....	21.00	.375	11
MgO.....	11.50	.287	9
Fe ₂ O ₃	11.53	.072	2
Al ₂ O ₃	3.50	.034	1
H ₂ O.....	1.00		
	99.53		

Sp. Gr. 3.5, Beck.

3.43-3.46, Brewer.

This analysis gives the formula $\text{Ca}_{11}\text{Mg}_9\text{Fe}_4\text{Al}_2\text{Si}_{25}\text{O}_{75}$ which does not appear to be a simple mixture of isomorphous silicates, but to consist of $9(\text{CaMgSi}_2\text{O}_6) + 2\text{Fe}_2\text{O}_3 + \text{Al}_2\text{Si}_3\text{O}_9$, leaving $\text{Ca}_2\text{Si}_3\text{O}_9$ or approximately 3 (CaSiO_3). From the above formula deduced from Vanuxem's analysis the hudsonite could not be classed with hedenbergite, but the two analyses of Smith and Brush given below, place it intermediate between hedenbergite and augite.

The analysis of Smith and Brush (Ref. 47), is as follows :

SiO ₂	39.30	38.58
Al ₂ O ₃	9.78	11.05
FeO	30.40	30.57
CaO.....	10.39	10.32
MgO	2.98	3.02
MnO	.67	.52
K ₂ O	2.48	4.16
Na ₂ O.....	1.66	
H ₂ O	1.95	1.95
	99.61	100.17

These analyses of Smith and Brush cannot be calculated out in a satisfactory manner. They both, however, contain a considerable percentage of the hedenbergite molecule.

Smith and Brush claimed that their analyses showed that the Hudsonite was a variety of augite. Kengott, on the other hand, thought that according to the analyses Hudsonite belonged to the amphiboles. Both Dana and DesCloiseaux placed it among the augites on account of the cleavage. Kengott notes (Ref. 27) that Hudsonite has a cleavage parallel to the prism of 124° , but is near hedenbergite in composition. Dana, in commenting on this, states that none of the specimens which he has seen show such a prism angle.

From Vanuxem's analysis this mineral would be classed as an augite, but the high percentage of ferrous iron in the analyses of Smith and Brush tend to class it with hedenbergite. It does not agree with the theoretical composition of hedenbergite in that it contains too small a percentage of lime, and is, therefore, as stated above, intermediate between augite and hedenbergite.

There is a small specimen of this mineral in the Columbia University collection and another fine specimen in the collection of the New York State Museum at Albany.

SAHLITE.

Willsborough, Essex Co.—A granular green pyroxene associated with granular garnet and wollastonite occurs in a vein at this locality (Ref. 2, p. 289). The grains are nearly transparent and the material has a semivitreous lustre. An analysis by Seybert gave:

	Percentage.	Ratio.	Prop. parts.
SiO ₂	50.33	.839	60
FeO	20.40	.283	20
CaO	19.33	.345	25
MgO	6.83	.170	13
Al ₂ O ₃	1.53	.914	1
H ₂ O	.66		
MnO	tr		
	99.08		

Sp. Gr. 3, 377.

The above analysis corresponds to the formula $Mg_3 Fe_{20} Ca_{25} Al_1 Si_{60} O_{179}$, which is intermediate in composition between sahlite and hedenbergite, but nearer to the former.

An analysis of pyroxene from Edenville, analyzed by G. W. Hawes (Ref. 19), was published, together with one of hornblende from the same locality, as proofs that "when parallel growths of two minerals occur, which under different conditions can be made to crystallize from the same material, chemical composition determines the difference."

	Percentage.	Ratio.	Prop. parts.
SiO ₂	51.05	.85	100
Al ₂ O ₃	2.02	.019	2
FeO	12.18	.169	20
CaO	22.07	.394	47
MgO	10.02	.250	30
Fe ₂ O ₃	1.36	.0085	1
MnO	.12	.016	2
H ₂ O	.34		
	99.10		

This pyroxene also approximates sahlite in composition giving the formula



DIOPSIDE.

DeKalb, St. Lawrence Co.—The crystals from this locality are usually transparent and light green to colorless. They vary in size from a half inch to an inch and a half long. No doubly terminated ones have been seen. The faces of the prismatic zone are mostly smooth and bright, but sometimes have longitudinal striations. The terminal planes are invariably pitted, those on $u(111)$ and $\Delta(311)$ being more like deep interrupted striæ. A tabular habit parallel to $b(010)$ is frequent. Several combinations of forms occur, but the most general is $a(100)$, $b(010)$, $m(110)$, $c(001)$, $u(111)$, $s(111)$, $o(221)$, $\Delta(311)$ and sometimes $p(101)$ (Pl. XIII, Fig. 9). Other combinations are $a(100)$, $b(010)$, $m(110)$, $c(001)$, $u(111)$ (Pl. XVI, Fig. 4); $b(010)$, $m(110)$ and $u(111)$ (Pl. XVI, Fig. 8); and $u(111)$, $o(221)$, $c(001)$, $a(100)$, $b(010)$ and $m(110)$ (Pl. XVI, Fig. 3). The plane v is present on a few crystals, but is always very narrow. The clinodome $e(011)$ was seen on two crystals, one in the private collection of Prof. Egleston, and the other in the collection of Prof. A. H. Chester. It is a small triangular face. A common habit of the DeKalb diopsides is the unequal development of $u(111)$, the left-hand face being often large, while the right-hand one is so narrow as to appear wanting.

No basal parting has been observed in the fresh crystals, but is universally present in the altered ones, which are of a greenish white color and opaque.

The DeKalb diopsides have been described by V. Rath (Ref. 38), who noted the forms $a(100)$, $b(010)$, $m(110)$, $c(001)$, $u(111)$ and $v(221)$. He states that they are often intergrown with hornblende and also mentions a twinning parallel to $a(100)$. The pyramid $v(221)$ was first recorded by him from this locality.

The two forms of diopside figured by Prof. Penfield in Dana's System of Mineralogy are the same as the first two mentioned above by the writer.

This diopside is among the purest of pyroxenes found with the State, as the following analysis shows.

SiO ₂	54.86
FeO	1.30
CaO	24.13
MgO	18.14
Al ₂ O ₃	.75
Alkalies	.35
Ign.....	.10
	99.89

Sp. Gr. 3.29.

This corresponds very closely with an analysis made by E. L. Sperry and given in Dana's System of Mineralogy, which is:

	Percentage.	Ratio.	Prop. parts.
SiO ₂	55.12	.9186	235
Al ₂ O ₃	.40	.0039	1
FeO	1.12	.0155	4
CaO	25.14	.449	115
MgO.....	18.15	.4537	116
K ₂ O.....	.02		
Na ₂ O	.45		
Ign.....	.17		
	100.47		



Sp, Gr. 3.286.

The above analysis gives us the formula $\text{Ca}_{115} \text{Mg}_{116} \text{Fe}_4 \text{Al}_2 \text{Si}_{235} \text{O}_{708}$ which corresponds very closely to the diopside formula, $\text{Ca Mg Si}_2 \text{O}_6$.

The optical constants of this diopside were determined as follows:

C : t =	40°
	Na.
<i>a</i>	1.6749
<i>β</i>	1.6852
<i>γ</i>	1.7013
<i>γ</i> — <i>a</i>	.0264
2 W	77° 42'
2 V	59° 30'
2 E	114° 40'

It will be seen that the indices of refraction are somewhat higher than those given below.

K. Zimanyi (Ref. 60) obtained the following values for diopside from DeKalb. The determinations were made on plates cut perpendicular to the first and second middle lines, and were 5.8 and

6.10 mm. in diameter respectively. The temperature at which the measurements were made was 15.25° – 25.75° C.

α	1.6674
β	1.6745
λ	1.6961
2 V =	$60^{\circ} 18'$
2 E =	$114^{\circ} 29'$

Direct measurement of the optic axes in Na light gave:

2 E =	$114^{\circ} 3'$	22° C.
2 H =	$60^{\circ} 46'$	
2 H =	$122^{\circ} 9'$	

The indices of refraction as determined by Zimanyi are still lower than those of Ala, which Des Cloiseaux (Man. Min. 1862, 1 p. 55), Dufet, Bull. Fr. Min. Soc., 1887, X, p. 290, Wulffing and Schmidt, Zeitschr. fur. Krystu. Min. 1893, XXI.

Edenville, Orange Co.—Rammelsberg gives in his Mineralchemie (Ref. 37), an analysis of a large bluish crystal from Edenville, which is as follows:

	Percentage.	Ratio.	Prop. parts.
SiO ₂	55.01	.917	13
FeO.....	4.95	.099	1
CaO.....	22.80	.407	6
MgO.....	16.95	.424	6
H ₂ O.....	.36		
	100.07		

Sp. Gr. 3.94.

The above analysis calculated out gives Ca₆Mg₆FeSi₁₃O₃₉ which corresponds pretty closely to the formula Ca Mg Si₂O₆.

Edwards, St. Lawrence Co.—The only specimens which the writer has seen from this locality are some crystals in the collection of Prof. Egleston. They are of simple habit and the combination of forms is $a(100)$ and $b(010)$ broad, $m(110)$ narrow $u(111)$ and $c(001)$. The faces have altered to tremolite.

Macomb St. Lawrence Co.—There is one group of small glassy crystals in the Columbia University collection. The crystals are tabular parallel to $b(010)$ and have the faces $a(100)$, $b(010)$, $m(110)$ $c(001)$ and $u(111)$. The associated minerals are albite, calcite and graphite.

Pierrepont, St. Lawrence Co.—Transparent crystals tabular parallel to $b(010)$ are common. They occur mostly as small groups of interlacing crystals. Basal and orthopinacoidal twin-

ning and the accompanying parting are common. The general combination of forms is $a(100)$, $b(010)$, $m(110)$ and $c(001)$. Another form figured by Prof. Penfield in Dana's System of Mineralogy, 1893 shows $a(100)$, $b(010)$, $c(001)$, $u(111)$, $v(221)$ and $p(\bar{1}01)$. Parallel growths of pyroxene with hornblende are frequent. (Ref. 38) and G. V. Rath has described crystals from Pierrepont, whose prism faces were covered with numerous small individuals. (Ref. 38.) The extinction angle of the Pierrepont diopsides is 37° .

Pitcairn, St. Lawrence Co.—An unusual form from this locality, and belonging probably with the diopsides, is a small group of crystals in the collection of Cornell University. The crystals are $\frac{1}{3}$ – $\frac{1}{2}$ an inch long, with bright faces. They are of very simple form showing only the planes $m(110)$, $u(111)$ and $s(111)$, (Pl. I, Fig. 8).

Port Henry, Essex Co.—The occurrence of white pyroxene as an unaltered core of the serpentine grains and masses in the opheolites of the eastern Adirondacks has long been known, but so far as the writer is aware the occurrence of white pyroxene crystals free from serpentine is uncommon. During the summer of 1893, Prof. Kemp found a great quantity of this interesting variety in a limestone quarry north of Port Henry, where it occurs together with yellow titanite, hairbrown amphibole and graphite. The amphibole is idiomorphic with respect to the pyroxene and titanite. Scales of graphite surround the pyroxene and penetrate it, and shots of the same mineral often appear on the faces in the prismatic zone, but none were noticed on the terminal faces, neither were there any on the amphibole or titanite.

The diopside individuals though usually white are sometimes pink. They are translucent, and vary in length from one-tenth to half an inch, with smooth bright faces. A strong basal parting is not uncommon, but is wanting in the perfectly fresh and transparent individuals. An orthopinacoidal parting is occasionally met with.

The general combinations of forms occur, viz., $a(100)$, $b(010)$, $m(110)$, $c(001)$, $u(111)$, $s(\bar{1}11)$ and $p(\bar{1}01)$. (Pl. II, Fig. 10), and $a(100)$, $b(010)$, $m(110)$, $c(001)$, $e(011)$ and $p(\bar{1}01)$. (Pl. II, Fig. 9). The pyramids and clinodomes rarely occur on the same crystal. One specimen in the private collection of Prof. Kemp has the face $o(221)$.

An analysis of the fresh material gave

	Percentage.	Ratio.	Prop. parts.
SiO ₂	54.57	.9095	70
FeO.....	1.80	.0250	2
CaO.....	23.25	.4151	32
MgO	17.78	.4432	35
Al ₂ O ₃	1.12	.0129	1
K ₂ O.....	.7		
Ign.....	.38		
	99.80		

Sp. Gr. 3.27.

The above analysis corresponds to the formula $\text{Ca}_{32}\text{Mg}_{35}\text{Fe}_2\text{-AlSi}_{70}\text{O}_{212}$ which is practically that of diopside. The optical constants are

C:c	41°
	Na.
α	1.6683
β	1.6730
γ	1.6902
$\gamma-\alpha$	.0219
2 W	= 73° 21'
2 V	= 56° 30'

The white pyroxenes of this region are of interest as being the source of much of the serpentine in the opicalcites of Port Henry, Essex Co., and Bolton, Thurman and Warrensburg in Warren Co.

This process of alternation has been studied and described in detail by G. P. Merrill. (Ref. 34). The blotches of yellowish and greenish serpentine, or serpentine and white pyroxene occur in the opicalcite near Port Henry from an inch to a foot or more in diameter. In the quarry of the Ophite Marble Co., the serpentine with white pyroxene nuclei is said to be very common, and all stages of alternation can be traced. The following is an analysis from Dr. Merrill's paper of the fresh pyroxene and the serpentine crust.

	Pyroxene.	Serpentine.
SiO ₂	55.26	42.17
Al ₂ O ₃	.22	.30
Fe ₂ O ₃	.22	1.57
FeO.....	.57	.64
CaO	24.48	
MgO.....	19.53	41.33
MnO.....	tr.	
H ₂ O.....		13.72
	100.28	99.73

The pyroxene is therefore, as pointed out by Dr. Merrill, a very pure lime magnesian variety, corresponding pretty nearly to the formula of diopside $\text{Ca Mg Si}_2\text{O}_6$, and its conversion into serpentine consists in the assumption of water and the giving up of its lime, which crystallizes as calcite. A comparison of the preceding analysis with that of the white pyroxene analyzed by the writer, and given on a previous page, shows a close similarity in composition. The latter corresponds still more closely, however, with the white pyroxene which Dr. Merrill has described from Montville, N. J. The composition of the latter is :

SiO_2	51.45	48.17
Ignit.....	1.08	.12*
CaO	24.02	21.96
CaCO_3		10.44
MgO	18.43	17.61
MgCO_3		.71
Al_2O_3	2.94	.52
Fe_2O_3	1.06	.18
FeO	.96	.24
MnO	tr	
SO_3	tr	tr
K_2O	und.	und.
Na_2O	und.	und.
	99.94	99.95

In this connection there may be mentioned the serpentine which was found in aqueduct shaft 2 (Ref. 33) in New York city. It results from the hydration of a white monoclinic pyroxene, showing under the microscope nearly rectangular prismatic cleavages, and giving extinction angles as high as 44° . The alteration is accompanied with the formation of abundant secondary calcite.

Beck (Ref. 2, p. 289) has noted a light green pyroxene from a locality half a mile north of Port Henry. It is said to be intimately mixed with secondary calcite.

Russel, St. Lawrence Co.—In addition to the greenish-black crystals from this locality which were mentioned under the head of augite, there are found greenish-white crystals resembling the forms from DeKalb and also green glassy ones of prismatic habit.

The greenish-white ones are nearly always strongly tabular parallel to b (010), and were observed to have the following com-

* H_2O .

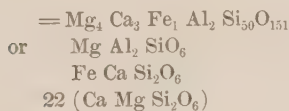
bination of forms: $a(100)$, $b(010)$, $c(001)$ (Pl. I, Fig. 4); $b(010)$, $m(110)$, $c(001)$ (Pl. I, Fig. 3); $a(100)$, $b(010)$, $m(110)$, $c(001)$ and $u(111)$, similar to form from Gouverneur shown in Pl. IV, Fig. 4.

Nearly all of the individuals show a strong basal parting, due to twinning. Uralitization is probably better developed in these crystals than those from any other locality in the State. All stages of transition can be seen from the pyroxene crystal, whose faces present a slightly fibrous appearance, to one whose whole mass has been converted into fibrous amphibole. Sometimes the crystals are cracked apart and the separated portions held together by amphibole fibres. Penetrations of one diopside crystal into another are not uncommon. One crystal from this locality in the Root collection at Hamilton College is $4 \times 4 \times 12$ inches in size. Another in the Columbia University collection had a small, perfectly formed crystal of mica similarly oriented included in it.

The green glassy crystals are all of simple prismatic habit, and show only the forms $a(100)$, $b(010)$, $m(110)$. They are terminated by parting planes parallel to the base. The faces of the prismatic zone sometimes show traces of uralitization, but decomposition takes place usually along the parting planes, resulting in powdery alteration product, probably serpentine. Twinning parallel to $a(100)$ and $c(001)$ is seen in nearly every specimen, and a strong prismatic cleavage is frequent.

The following analysis shows the composition of this green glassy diopside.

	Percentage.	Ratio.	Prop. parts
SiO ₂	54.94	.9156	50
FeO.....	1.29	.0179	1
CaO.....	25.38	.4156	23
MgO.....	17.60	.4400	24
Al ₂ O ₃	2.42	.0236	1
Alkalies.....	.28		
	99.91		



Sp. Gr. 300.

The optical constants of the Russel diopside were determined to be,

C:r	37°
	Na
α	1.6626
β	1.6718
γ	1.6940
$\gamma-\alpha$	.0314
2W	77° 34'
2V	58° 56'

Parallel growths of amphibole and pyroxene are common at this locality and the late Prof. G. H. Williams has called attention to the fact that the lesser extinction angle always lies on the same side of the vertical axis. Prof. Williams has also described and figured a remarkable growth of dark green hornblende from Russel, around a crystal of pale green pyroxene. Both crystals have the clinopinacoids parallel, as is also the parting which is present in both. The specimen is about three inches long and is in the collection of Mr. C. Bement of Philadelphia.

GENESIS OF THE NEW YORK PYROXENES.

As previously stated, the pyroxenes occur under the following conditions:

1. As primary constituents of the igneous rocks.
2. In contact zones between the igneous rocks and the limestones.
3. Disseminated through the limestones in regions which have been subjected to dynamic metamorphism.
4. Associated with the bodies of magnetite ore.

The first case includes pyroxene occurring both in dikes and intrusive masses, and the mode of formation is apparent, the pyroxene representing one of the products of crystallization from an igneous magma. It is among the earliest minerals to crystallize out, and is preceded by magnetite, apatite, zircon and sometimes biotite.

When thus occurring as a constituent of the igneous rock it belongs to the variety augite, which is essentially a mineral of igneous rocks. The experiments of Berthier, and Fouque and Levy (*Synthese des Mineralogie des Roches*, Paris, 1882) have shown that augite can be easily produced artificially from a fused

mixture, in microlites and large crystals, and associated with the various minerals which accompany it in nature. Both temperature and chemical composition exert an influence. Augite being more stable at high temperatures will separate under such conditions, whereas if the crystallization takes place at a lower temperature hornblende is more likely to result. According to Vogt (*Zeitschr. für. Kryst. u. Min.*), if the relation of CaO to MgO becomes as 1.3 orthorhombic pyroxene separates instead of the monoclinic form.

When an igneous rock intrudes itself into a limestone or dolomite, a change usually takes place in the latter along and near the line of contact. This change consists first in an increase in the coarseness of the limestone and secondly in the abundant development of minerals in the contact zones or disseminated through the limestone near it. This production of contact minerals has been frequently noticed and described.

In contact metamorphism the intensity and extent of the change depends on the temperature, mineralogical and structural character of the eruptive rock, also on the duration of its action and the area and conductivity of the rock affected.

The contact changes are brought about partly by the intrusion of the igneous mass, and partly by the action of mineralizers. The former can and have been produced artificially.

The minerals of the contact zones derive their material 1. from the igneous rocks, 2. from the limestone, 3. from below, being brought up by solutions stimulated by the intrusion of the igneous rock. The greatest development of contact minerals occurs in an impure limestone, or if the eruptive rock mingles with the limerock. (J. Roth p. 175.)

We should thus expect to find minerals rich in lime and magnesia, such as garnet, vesuvianite, pyroxene, wollastonite, amphibole, chondrodite, etc.

The presence of mineralizers is often shown by the occurrence of fluorite, tourmaline and chondrodite, and indeed it has been found that the presence of mineralizers is an essential factor in aiding the formation of some of these minerals.

Diopsides and augites poor in alumina are especially abundant in the limestone contact zone, and their frequent occurrence at such localities lining the sides of fissures filled with quartz or calcite, rather point to a possible formation sometimes by wet

methods, under great pressure and high temperature no doubt, as has been done artificially.

In some cases the effect of the igneous rock seems to be to cause a molecular rearrangement in the limestone, resulting in the formation of new minerals by segregation. Thermal metamorphism does not seem to involve any alteration in the bulk of the rock affected. Whatever part water plays, it does not act as a medium in the transfer of material, and it is also probable that the transportation is confined within narrow limits (A. Harker—*The Migration of Material During the Metamorphism of Rock Masses*, Jour. Geol. I, p. 574).

The opicalcites of the eastern Adirondacks furnish an excellent example of the mode of formation of pyroxene by segregation resulting from the intrusion of the gabbros (Ref. 26). These opicalcites contain great masses of silicates, which have been distorted by the violent dynamic metamorphism which the rock has been subjected to. They also indicate the flowing of the limestone under pressure. These limestones were originally magnesian limestones containing great quantities of impurities, which have segregated to form the pyroxenes and other silicates. These silicates often form masses 23–30 feet thick.

In support of the theory that the pyroxene results from a magnesian limestone, Prof. Kemp gives the following two analyses made by the writer, the first that of pieces of the white limestone at Port Henry, which were free from silicates and the second analysis, that of the white pyroxene occurring in it.

	Limestone.	Pyroxene.
SiO ₂		54.57
Al ₂ O ₃	1.72	1.32
Fe ₂ O ₃		
FeO.....		1.62
CaO.....	46.79	23.23
MgO.....	5.10	17.78
K ₂ O.....		.70
Na ₂ O.....		.32
H ₂ O.....	42.42	
	96.03	99.54

From the above analyses it will be seen that the bases and silica have collected to form the pyroxene.

The common occurrence of white pyroxene in the metamor-

phosed magnesian limestones of West Chester, Dutchess and Putnam Counties has been described and it was mentioned that the pyroxenes occurred in bunches filling cavities or in streaks associated with quartz. So far as the writer is aware, none of the occurrences in these localities are associated with igneous intrusions, and the probability, therefore, is that these pyroxenes were produced by the regional metamorphism to which these dolomites were subjected. Two methods of formation are, therefore, possible: 1. Segregation from the surrounding rock; 2. Deposition from solutions which brought the material from a deep-seated source. The presence of associated quartz and the occurrence of the crystals in veins or cavities would seem perhaps to favor the second hypothesis and still it is possible that the pyroxene in these dolomites has been caused by a segregation of material from the surrounding limestone which contains all the elements needed in the formation of these leucaugites.

The formation of pyroxene by regional metamorphism has been described by Westgate from Warren Co., N. J. (*Amer. Geol.*, 1894). W. H. Hobbs has also described the formation of tremolite and large pyroxene crystals along the Housatonic fault, in Massachusetts (*The Structure of the Housatonic Valley* lying east of Mt. Washington, *Jour. Geol.*), and Fairbanks mentions a similar case of the formation of green pyroxene in California (*Geol. of the Coast Ranges of Cal., B. G. S. A., VI, p. 71*).

In the last class of occurrences mentioned, viz., the formation of pyroxene around ore bodies, there is still considerable doubt as to the theory of the origin of most of the pyroxenes. They may have been formed by segregation, but this is a point for further investigation.

PLATE XIII.

1. Augite, Monroe Township, Orange Co.— a (100), b (010), m (110), u (111), s ($\overline{111}$), o (221), p (101).
2. Tilly Foster, Putnam Co.— a (100), b (010), m (110), f (310), o ($\overline{221}$), p (101).
3. Russel, St. Lawrence Co.— b (010), m (110).
4. Diopside, Russel, St. Lawrence Co.— a (100), b (010), c (001).
5. Monroe Township, Orange Co.— a (100), b (010), m (110), u (111), s (111), o (221), z (021).
6. Augite, St. Lawrence Co.— m (110), b (010), u (111), Δ (331).
7. Augite, Pitcairn, St. Lawrence Co.— a (100), b (010), m (110), c (001), u (111), s (111), o (221).
8. Diopside, Pitcairn, St. Lawrence Co.— m (110), u (111), s ($\overline{111}$).
9. Diopside, DeKalb, St. Lawrence Co.— a (100), b (010), m (110), c (001), u (111), v (221), o ($\overline{221}$), Δ (331), p (101).

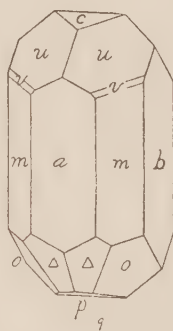
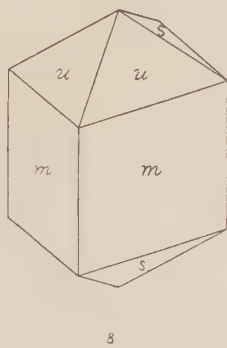
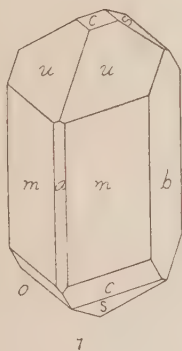
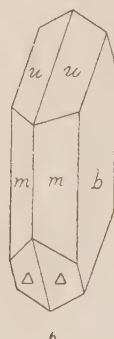
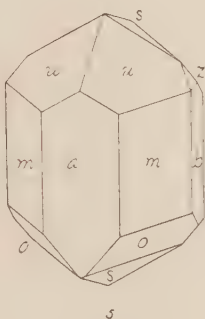
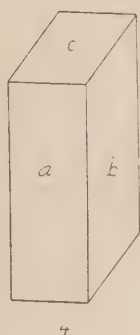
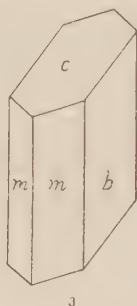
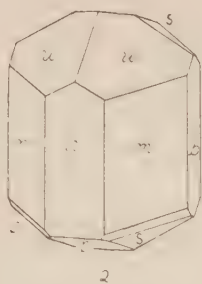
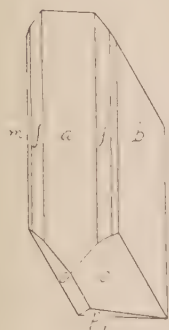
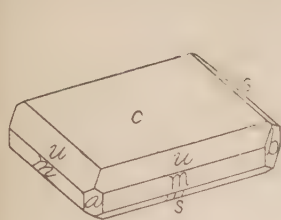
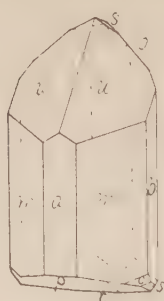


PLATE XIV.

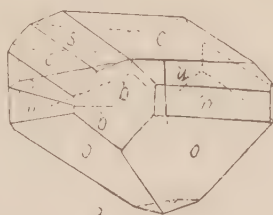
1. Leucaugite, Edenville, Orange Co.— $a(100)$, $b(010)$, $m(110)$, $c(001)$, $u(111)$, $s(\bar{1}11)$.
2. Augite, Rossie, St. Lawrence Co.—Shows hemihedral distribution of planes.
3. Leucaugite, Edenville, Orange Co.—shows hemihedral distribution of planes, and twinned lower half of crystal.
4. Augite, Gouverneur, St. Lawrence Co.— $a(100)$, $b(010)$, $m(110)$, $u(111)$, $s(\bar{1}11)$.
5. Augite, Highlands of Hudson, Orange Co.— $a(100)$, $b(010)$, $m(110)$, $c(001)$, $e(\bar{1}01)$.
6. Augite, Warwick, Orange Co.— $a(110)$, $b(010)$, $m(110)$, $c(001)$, $u(111)$, $s(\bar{1}11)$, $o(211)$, $p(\bar{1}01)$.
7. Augite Warwick, Orange Co.— $a(100)$, $b(010)$, $m(110)$, $c(001)$.
8. Augite, Cheever Mine, Pt. Henry, Essex Co.— $a(100)$, $b(010)$, $m(110)$, $c(001)$, $u(111)$, $s(\bar{1}11)$.
9. Diopside, Pt. Henry, Essex Co.— $a(100)$, $b(010)$, $m(110)$, $c(001)$, $e(011)$, $p(\bar{1}01)$.
10. Diopside Pt. Henry, Essex Co.— $a(100)$, $b(010)$, $m(110)$, $c(001)$, $u(111)$, $s(\bar{1}11)$, $p(\bar{1}01)$.
11. Black augite, Hammondville, Essex Co.— $a(100)$, $b(010)$, $m(110)$, $c(001)$, $s(\bar{1}11)$.
12. Tilly Foster, N. Y.— $a(100)$, $b(010)$, $m(110)$, $c(001)$, $s(\bar{1}11)$.



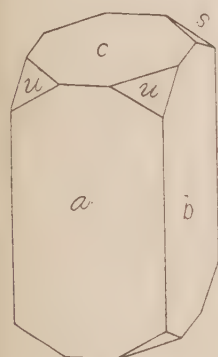
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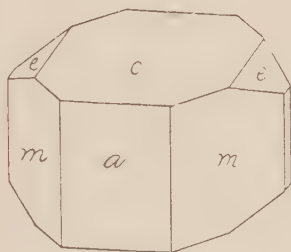
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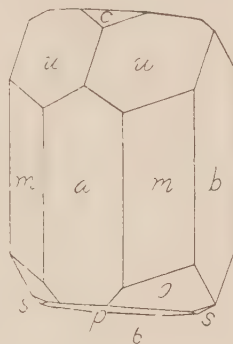
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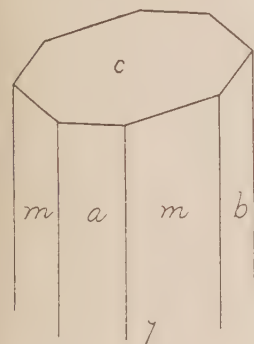
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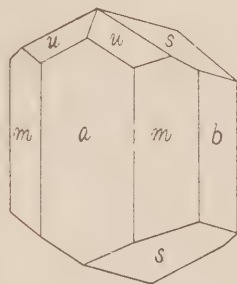
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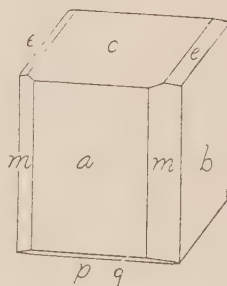
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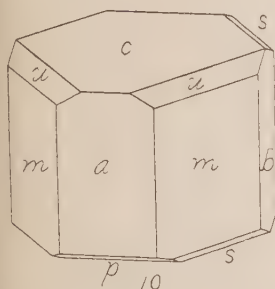
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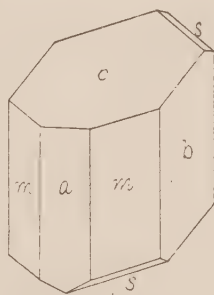
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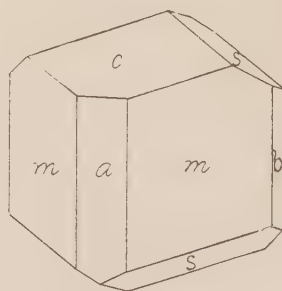
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PLATE XV.

1. Augite, Monroe Township, Orange Co.—Twinned parallel to a . Shows $a(100)$, $b(010)$, $m(110)$, $e(011)$.
2. Leucaugite, Sing Sing, Westchester Co.— $a(100)$, $b(010)$, $m(110)$, $o(\bar{2}21)$.
3. Augite, Monroe Township, Orange Co.— $a(100)$, $b(010)$, $m(110)$, $c(001)$, $e(011)$.
4. Leucaugite, Sing Sing, Westchester Co.— $a(100)$, $b(010)$, $m(110)$, $v(221)$, $o(\bar{2}21)$, $c(001)$.
5. Augite, St. Lawrence Co.— $m(110)$, $b(010)$, $u(111)$, $o(221)$, $\lambda(311)$.
6. Leucaugite, Paterson, Dutchess Co.— $a(100)$, $b(010)$, $m(110)$, $v(221)$, $o(221)$, $p(101)$, $c(001)$.
7. Augite, Russel, St. Lawrence Co.— $a(100)$, $b(010)$, $m(110)$, $p(101)$, $u(111)$.
8. Augite, Diana, Lewis Co.—Twinned parallel to $a(100)$. Shows $a(100)$, $b(010)$, $m(110)$, $p(101)$, $o(221)$, $\lambda(311)$.
9. Augite, Natural Bridge, Lewis Co.— $a(100)$, $b(010)$, $m(110)$, $u(111)$, $s(\bar{1}11)$, $o(221)$.

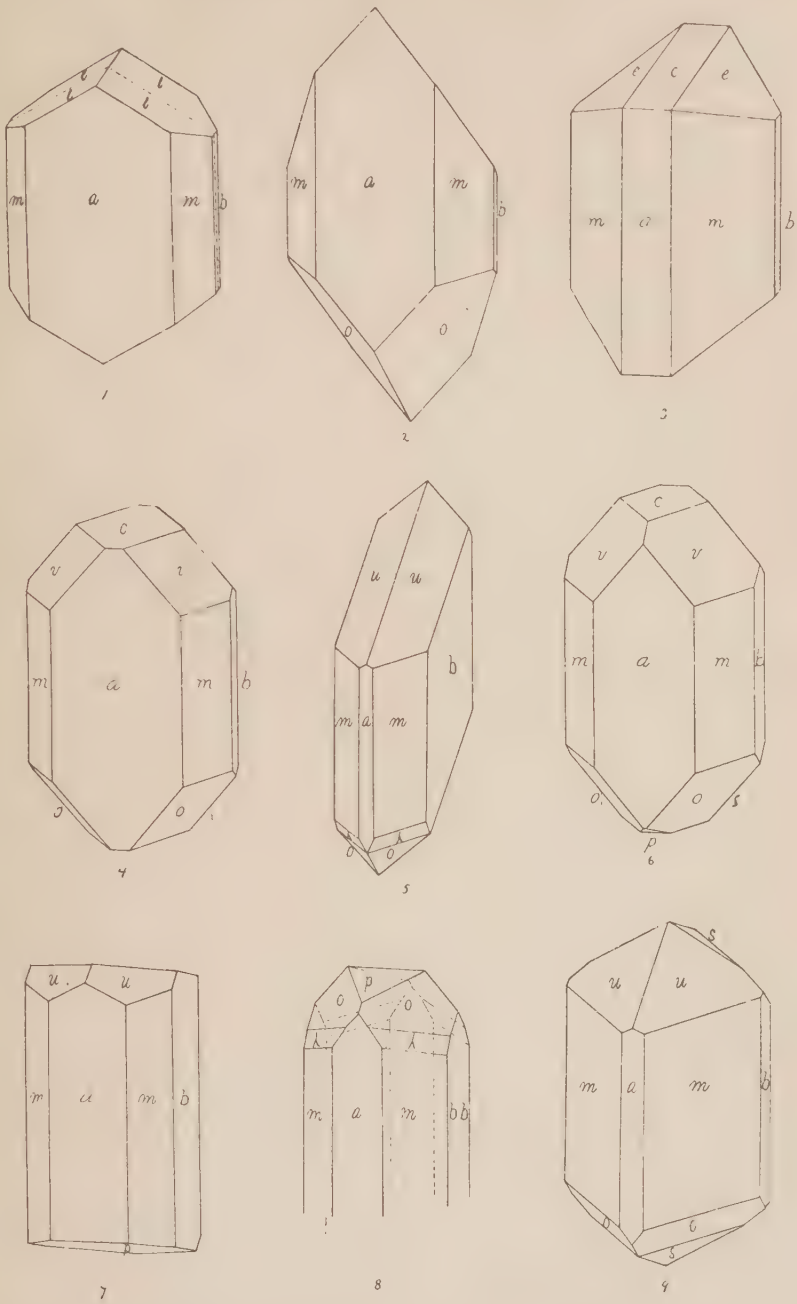
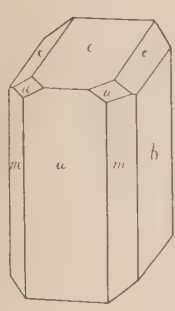


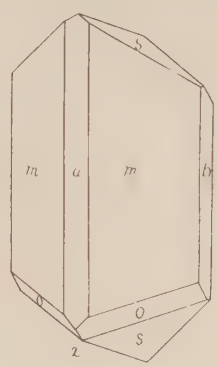


PLATE XVI.

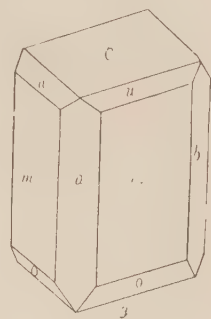
1. Diana, Lewis Co.— $a(100)$, $b(010)$, $m(110)$, $c(001)$, $u(111)$, $e(011)$.
2. Augite, Keene, Essex Co.— $a(100)$, $b(010)$, $m(110)$, $s(\bar{1}11)$, $o(221)$.
3. Diopside, DeKalb, St. Lawrence Co.— $a(100)$, $b(010)$, $m(110)$, $c(001)$, $u(111)$, $o(\bar{2}21)$.
4. Diopside, DeKalb, St. Lawrence Co.— $a(100)$, $b(010)$, $m(110)$, $c(001)$, $u(111)$.
5. Augite, Rossie, St. Lawrence Co.— $a(100)$, $b(010)$, $m(110)$, $u(\bar{1}11)$, $v(221)$.
6. Augite, Diana, Lewis Co.— $a(100)$, $b(010)$, $m(110)$, $u(111)$, $s(\bar{1}11)$, $o(221)$, $z(021)$.
7. Augite, Adams Lake.— $a(100)$, $b(010)$, $m(110)$, $u(111)$, $s(\bar{1}11)$, $o(212)$, $p(\bar{1}01)$.
8. Diopside, DeKalb, St. Lawrence Co.— $b(010)$, $m(110)$, $u(111)$.
9. Augite, Tilly Foster, Putnam Co.— $a(100)$, $b(010)$, $m(110)$, $u(111)$, $s(111)$, $o(221)$, $p(\bar{1}01)$.



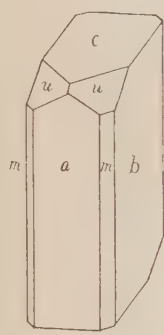
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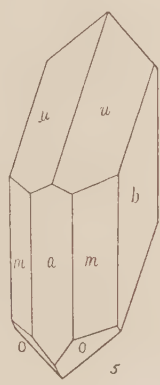
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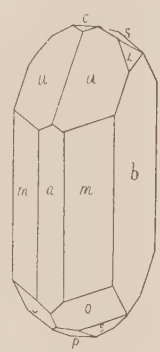
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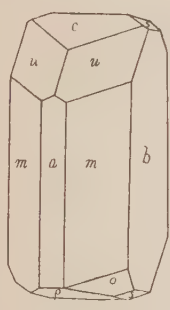
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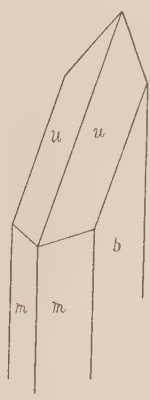
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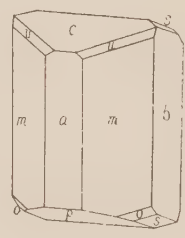
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